HOUSE No. 2260

The Commonwealth of Massachusetts

SPECIAL REPORT

OF THE

DEPARTMENT OF PUBLIC HEALTH RELATIVE TO VARIETIES AND PREVALENCE OF MOSQUITOES IN THE COMMONWEALTH

UNDER CHAPTER 14 OF THE RESOLVES OF 1939

DECEMBER, 1940

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The Commonwealth of Massachusetts

SPECIAL REPORT OF THE DEPARTMENT OF PUBLIC HEALTH RELATIVE TO VARIETIES AND PREVALENCE OF MOSQUITOES IN THE COMMONWEALTH.

[Public Health.]

DECEMBER 4, 1940.

To the General Court of Massachusetts.

In accordance with the authority delegated to it, the Department of Public Health, in co-operation with the Federal Work Projects Administration, has investigated the prevalence and the seasonal and geographical distribution of mosquitoes throughout the Commonwealth as provided by chapter 14 of the Resolves of 1939. This resolve is as follows:

Resolved, That the department of public health is hereby authorized to investigate, in co-operation with the Federal Work Projects Administration or its successor, the prevalence and the seasonal and geographical distribution of mosquitoes throughout the commonwealth. For said purpose said department may expend for services, other than services of said Federal Work Projects Administration or its successor, and for traveling expenses, supplies, materials and equipment, a sum not exceeding seventeen thousand five hundred dollars, which sum is hereby appropriated from the General Fund or ordinary revenue of the commonwealth in advance of final action on the general appropriation bill, pursuant to a recommendation of the governor to that effect. Said department shall report its recommendations, if any, together with drafts of legislation necessary to carry such recommendations into effect, by filing the same with the clerk of the house of representatives on or before the first Wednesday of December in the year nineteen hundred and forty.

This resolve was passed and the funds made available in response to a request from His Excellency the Governor in a special message to the General Court dated April 12, 1939, in which reference was made to an epidemic of en-

cephalomyelitis (horse sleeping sickness) in certain parts of the Commonwealth which was believed to have been the source of encephalitis in humans. In that message to the Legislature it was pointed out that this disease is extremely dangerous to young people, and that there is a considerable fear among health authorities that there may be a recurrence of the epidemic. Chapter 14 of the Resolves of 1939 was approved on May 9, 1939.

During the summer of 1938 there were 269 deaths from encephalomyelitis in horses, and 34 cases of encephalitis with 24 deaths among humans. This was the first time that the disease in humans was recognized as having been caused by the virus of encephalomyelitis of horses. While this disease was extremely prevalent in the summer of 1938, there were only 12 suspicious cases in horses in the summer of 1939 and only 8 in 1940, of which only 2 in 1939 and none in 1940 were proven. There was only 1 suspicious human case in 1939, while none have thus far been reported in 1940.

Following the epidemic of encephalomyelitis in 1938 the Department, at its meeting on October 11, 1938, acting under the provisions of section 6 of chapter 111 of the General Laws, as amended by chapter 265 of the Acts of 1938, changed the list of diseases declared dangerous to the public health by the removal of "Encephalitis Lethargica," as it then appeared, and substituting in place thereof the term "Infectious Encephalitis," and the Department also provided that the minimum period of quarantine of the patient be one week after the onset of the disease in an insect-free room.

While as complete an investigation as was practicable was made in 1939 of the prevalence and geographical distribution of mosquitoes throughout the Commonwealth, conditions during the investigation were unfortunate because the year 1939 was one of low rainfall and consequently one when mosquitoes were less prevalent than during the epidemic of 1938 and during years of normal rainfall. During the year 1938 there was an excess of about 11.7 inches

of rainfall above the normal throughout the State as a whole, or an excess of 26 per cent, while in 1939 there was a deficiency of some 5.5 inches of rainfall, or 13 per cent below the normal.

With the co-operation of the Work Projects Administration, and with the use of certain rooms and consulting services of Harvard University, over 23,000 specimens of adult, biting mosquitoes were collected and over 249,000 specimens of larvae were collected. All of these specimens have been examined by entomologists and identified by species. Fifty-six different species of mosquitoes were collected, and of these, investigations have shown that six are known vectors of encephalomyelitis in animals. Of the various mosquitoes and larvae collected, 22.1 per cent of the adult mosquitoes and 2.9 per cent of the larvae were determined to have been of the species capable of transmitting this disease. Collections were made in all but two of the municipalities of the Commonwealth, and from those collections the distribution of the species capable of transmitting the disease was determined. One species, Aedes vexans, was found in practically every municipality in the State.

The collections cannot be considered in any way an exact numerical measure of the prevalence of mosquitoes in any given portion of the State, but they do show where the different species are found. A definite numerical determination of the prevalence of mosquitoes would be impracticable. The number of collections varied more in accordance with the interest and ability of the personnel engaged in the investigation than with the actual number of mosquitoes and larvae present in a given territory. Comparatively few collections were made in Suffolk and Hampshire counties. Large collections were made in Middlesex, Worcester, Berkshire, Plymouth and Essex counties. A very considerable number of mosquitoes were collected in Barnstable County and on the islands of Martha's Vineyard and Nantucket, where rather complete work in mosquito control has been carried on under the direction of the State Reclama-

tion Board, the results of which have been to enhance the real estate and recreational values of these regions.

Some mosquito collections were made by the Department's representatives, beginning the week of April 22, 1939, before the resolve was passed, but these collections were small in number and large scale collections were not started on a state-wide basis until the first week in July. They were continued through October, only scattered collections in certain areas being made thereafter. There was a very marked falling off in collections during the last week in October. The maximum collections of larvae occurred during the week ending October 7, while the maximum collections of adults occurred during the week ending September 23. Following the week ending July 15 there was a falling off in the collections of adult mosquitoes, but an increase in the collections of larvae, due to more favorable breeding conditions.

The investigation has shown that mosquitoes of the varieties known to transmit sleeping sickness are less likely to be found in barns or houses than are other species. A large proportion of the known vectors of this disease were found in the vicinity of swamps and standing water and in wooded areas.

It may be concluded from this investigation that in times when there is danger of the occurrence of encephalomyelitis, children and adults should avoid swamps and wooded areas, and very young children should be kept in screened houses or other enclosures where they cannot be reached by mosquitoes. During such periods horses should be kept in barns rather than in the open.

A very considerable amount of information has been obtained through the investigation, under the provisions of chapter 14 of the Resolves of 1939, by both the Department of Public Health and the Work Projects Administration, relative to Massachusetts mosquitoes, and numerous reports have been mimeographed and distributed. It is impracticable to condense all of this information in a legislative report, but a considerable number of mimeographed

documents are available in the office of the Department of Public Health for distribution to members of the Legislature and others upon request.

Under the provisions of chapters 112 and 465 of the Acts of 1931, chapter 307 of the Acts of 1932, and chapters 89 and 371 of the Acts of 1933, a total of $600,000 was appropriated by the Legislature to provide for the employment of persons in carrying out mosquito control projects under the direction of the State Reclamation Board, and under these appropriations a very considerable degree of mosquito control of the salt marsh species has been effected. These salt marsh species are among the six vectors found to be capable of spreading the virus of encephalomyelitis, and this control work may be the reason why the disease was less prevalent in the coastal areas in Massachusetts in 1938 than it would have been if the control work had not been carried out. However, very little work has been done by the State in mosquito control in fresh-water areas, as the work in such areas involves a greater variety of control problems than does the salt marsh work. The fresh-water varieties of mosquitoes generally do not migrate to such great distances as the salt marsh varieties.

The recent epidemic of encephalomyelitis in Massachusetts started in West Bridgewater, and a considerable number of the cases occurred in the Taunton River Basin. About 70 per cent of the cases among horses occurred in a thirty-mile square extending from the mouth of the Taunton River in the south, to Boston in the north, and from the boundary of Rhode Island northeasterly to the coast line.

The human cases were rather widely distributed in Plymouth, Middlesex, Norfolk and Bristol counties, with six cases in Boston. The first cases in humans were in Brockton and Bridgewater. The municipalities in which about two thirds of the human cases occurred are known to contain swamp or marsh areas. The area referred to above includes a large variety of mosquito breeding places, among which is the large Hockamock or Great Cedar Swamp in

Bridgewater, Easton, Raynham, Taunton and West Bridgewater. This swamp is located not far from the middle of the territory in which the bulk of the cases in horses occurred. It covers an area of more than 7,000 acres and is the largest fresh-water swamp in the State. There has been considerable interest from time to time in the drainage of this swamp, in the reclamation of the land, and in the possibility of the establishment of a huge bird sanctuary. Collections of all of the known vectors of the disease were made in this area. Drainage of this swamp should be more adequately controlled.

In view of the evidence that encephalomyelitis may be spread by mosquitoes, and in view of the natural objection to mosquitoes, the Department is of the opinion that more adequate facilities should be provided for draining inland swamps and marshlands, thus extending the control over the species of mosquitoes capable of spreading this disease and of the mosquito pest in general. Mosquito control facilities should be made available in all known mosquito breeding areas throughout the State as a whole. Such a program can be accomplished in two ways, viz.:

1. By the State Reclamation Board, through special acts of the Legislature.

2. By local projects organized under chapter 252 of the General Laws, as amended.

The Department is of the opinion that any drainage works for mosquito control measures, including studies relating thereto, should be carried out by the State Reclamation Board, organized under General Laws, chapter 252.

It is recognized that complete mosquito control is impractical, and no further definite legislation is recommended by the Department in connection with its investigations under the provisions of chapter 14 of the Resolves of 1939, but with the approval of the State Reclamation Board suitable legislation and funds might well be provided to permit that Board to carry on effective drainage of inland swamp and marsh areas, to apply larvicides, and to use other means for more adequate mosquito control in fresh-water areas, with a view primarily to preventing the further

distribution of encephalitis. A basis of such legislation can be found in chapter 655 of the Acts of 1911 relative to the protection of the public health in the valley of the Neponset River, which provided for the dredging and deepening of the channel of that stream, and which provided for the construction of drains, trenches and ditches in the adjacent meadows.

Respectfully submitted,

PAUL J. JAKMAUH, M.D.,
Commissioner of Public Health.

RICHARD P. STRONG, M.D.
JAMES L. TIGHE.
GORDON M. HUTCHINS.
R. NELSON HATT, M.D.
RICHARD M. SMITH, M.D.
FRANCIS H. LALLY, M.D.

FINANCIAL STATEMENT.

Appropriation		$17,500 00
Expenditures:		
Personal services	$4,818 09	
Travel	9,048 81	
Equipment and supplies	1,561 95	
Rental of furniture and other equipment	771 13	
Stationery and office supplies	517 40	
Express, postage, telephone, etc.	477 81	
Books, maps, printing, etc.	266 07	
Drafting supplies	33 98	
Total expenditure		17,495 24
Balance		$4 76

REPORT OF THE DIRECTOR OF THE DIVISION OF COMMUNICABLE DISEASES OF THE DEPARTMENT OF PUBLIC HEALTH RELATIVE TO THE PREVALENCE AND THE SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF MOSQUITOES IN THE COMMONWEALTH.

November 1, 1940.

To Dr. Paul J. Jakmauh, *Commissioner of Public Health.*

Dear Sir: — Herewith is submitted a report relative to investigations made by the Department of Public Health in co-operation with the Federal Work Projects Administration, as authorized under the provisions of chapter 14 of the Resolves of 1939, relative to the prevalence and the seasonal and geographical distribution of mosquitoes throughout the Commonwealth.

The resolve was passed and funds made available in response to the request of his Excellency the Governor, which reads as follows (House, No. 2181):

The Commonwealth of Massachusetts,
Executive Department,
State House, Boston, April 12, 1939.

To the Honorable Senate and House of Representatives.

House Bill No. 399, a resolve providing for an investigation by the Department of Public Health, in co-operation with the Federal Works Progress Administration, relative to the varieties and prevalence of certain kinds of mosquitoes in the Commonwealth of Massachusetts, calls for an appropriation in the aggregate of $17,500. This sum will be the Commonwealth's contribution to the cost of the investigation, and will permit the Department of Public Health to investigate, in co-operation with the Federal Works Progress Administration, the prevalence and the seasonal and geographical distribution of mosquitoes throughout the Commonwealth.

Last summer there was an epidemic of encephalomyelitis in certain parts of our Commonwealth. This is an extremely dangerous disease to young people, and there is considerable fear among the authorities that

there may be a recurrence of this epidemic in the coming summer months. Work with relation to mosquitoes, to be effective, must be done in the month of May.

I therefore recommend this appropriation to be made in advance of the budget.

LEVERETT SALTONSTALL,
Governor of the Commonwealth.

EQUINE ENCEPHALOMYELITIS.

The Mosquito Survey was organized as a result of the 1938 outbreak of horse-sleeping sickness (equine encephalomyelitis) among humans, animals and birds in southeastern Massachusetts. This was the first time that the disease was recognized in this State; moreover, it was the first time that equine encephalomyelitis was demonstrated to infect species other than horses and mules. Equine encephalomyelitis is a newly recognized infectious virus disease. Its economic importance is great, as it kills thousands of horses and mules every year and is now known to be fatal in humans. Laboratory experiments have demonstrated that many species of small mammals and birds are susceptible. With its recognition among humans, the disease has become a problem which requires study to arrive at some method of control. The mosquito has been proved experimentally to be able to transmit the disease, and there is much evidence that certain species are the natural vectors. The objectives of the Mosquito Survey were: to collect and determine the various species of mosquitoes present in Massachusetts; to obtain data on the geographical distribution and the seasonal predominance of the different species; and to ascertain the possible relationship of such mosquitoes to certain diseases which are transmitted by these insects.

Varieties of Equine Encephalomyelitis.

Equine encephalomyelitis is a disease which may be due to one of four different varieties of virus. The clinical picture produced by each variety ranges from a mild and subacute form to one which is fulminating and acute. Similarly,

the varieties may be separated by well-recognized laboratory methods.

In the United States only the western and eastern varieties are known to occur. The western is limited to the area west of the Appalachian Mountains; epizoötics of this variety among horses have been characterized by a high attack rate, a low fatality rate, and a subacute form of this disease. The eastern variety, on the other hand, has been known to occur only along the Atlantic seaboard. In 1939 both the eastern and western varieties were reported from Alabama. Epizoötics of the eastern variety are characterized by a low attack rate, a high fatality rate, and a more acute and fulminating type of disease. Both varieties have been demonstrated to affect humans. However, because only a few cases of the disease have been recognized, it is impossible to describe exactly the characteristics of infection in man with these viruses. Nevertheless, with the information on hand, it seems likely that the western variety of this disease in man may be in many instances subclinical or mild, whereas the eastern variety causes an acute and fulminating type of disease not unlike that in horses. Many investigators have experimented with the mosquito transmission of this disease. At first, these experiments were difficult to interpret, due to the varying conditions under which they were performed. At the present time there are seven species of mosquitoes which have been demonstrated experimentally to transmit the eastern virus to laboratory animals. Two of these carriers were added to the list in 1939 by a worker at the Harvard Medical school, using material supplied by the survey. The western virus has been transmitted by eight species of mosquitoes. In all instances of transmission, the mosquito concerned belonged to the genus *Aedes*. Transmission experiments with the other genera of mosquitoes, *Culex*, *Anopheles*, *Theobaldia*, *Mansonia*, *Wyeomyia* and *Uranotaenia*, have thus far been negative.

Table I gives a summary of the transmission experiments. It is apparent that some mosquitoes have been shown to transmit one variety of the virus, but not the other. So

far as is known, there is no biological reason why any species of mosquitoes should be able to transmit one variety of equine encephalomyelitis virus and not the other. It is believed that eventually experiments will show that if a species can transmit one variety, it can also transmit the other. In all, there are ten species of *Aedes* mosquitoes which have transmitted the virus experimentally, but it is likely that they are not all of equal importance as vectors. Further investigation is needed to determine which species are actual vectors in nature and which are the most important as carriers of the disease.

Other Methods of Transmission.

A discussion of the epidemiology of equine encephalomyelitis would not be complete without mention of other experimental and field data. Laboratory experiments repeated by various workers have demonstrated that equine encepha-

TABLE I. — *Mosquitoes Known to Transmit Equine Encephalomyelitis to Laboratory Animals.*

NAME OF MOSQUITO.	Western Variety.	Eastern Variety.	Occurrence in Massachusetts.
Aedes aegypti	x	x	0
A. sollicitans	x	x	x
A. cantator	x	x	x
A. vexans	x	x	x
A. triseriatus[1]	–	x	x
A. atropalpus[1]	–	x	x
A. taeniorhynchus	x	x	x
A. dorsalis	x	–	x
A. albopictus	x	–	0
A. nigromaculis	x	–	0

[1] Work done at Harvard Medical School in 1939.

lomyelitis is not transmitted by direct contact. Susceptible animals, which were caged with infected ones, failed to contract the disease in spite of the intimate contact when mos-

quitoes were excluded. Field observations during epizoötics revealed that multiple infections of horses in the same stable or on the same farm were rare. The evidence is therefore against infection by direct contact.

In 1936 Syverton and Berry demonstrated that *Dermacentor andersoni*, the Rocky Mountain wood tick, was capable of transmitting experimentally the western variety. The continuity of the virus through all stages in the development cycle of the tick, including survival through the egg stage, was definitely demonstrated. There is in ticks, therefore, a potential vector and reservoir, especially during the winter months, when cases of equine encephalomyelitis are rare and the ticks are hibernating.

Besides ticks and mosquitoes, experiments on other potential insect vectors have been made, especially on those that habitually bite horses and mules. Riley studied the insect transmission of disease due to filterable viruses, and concluded that the stable fly, *Stomoxys calcitrans*, the horsefly, *Tabanus punctifer*, and the hornfly, *Haematobia serrata*, were not capable of being vectors of equine encephalomyelitis.

Possible Reservoirs of the Disease.

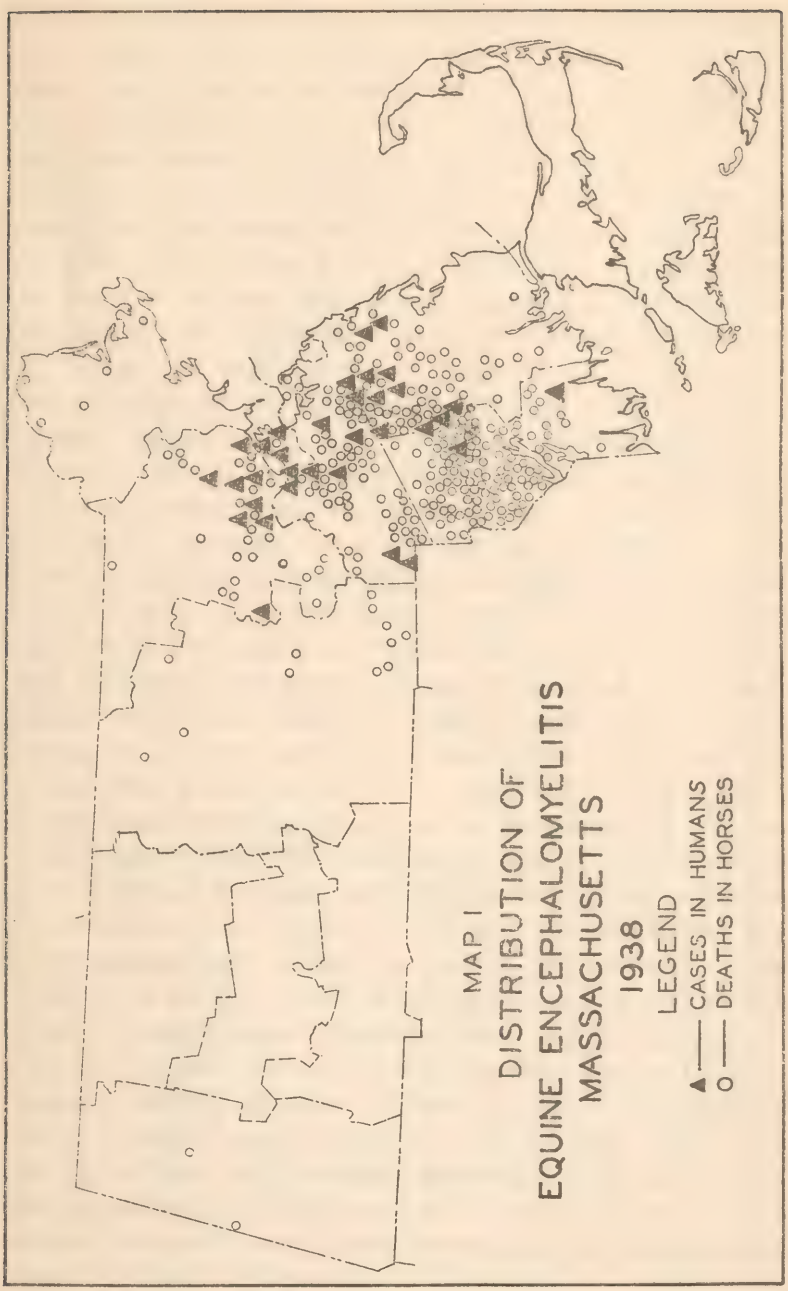
In a disease with a broad host selectivity, such as equine encephalomyelitis, it is not unlikely that the reservoir of the disease may be found in one or more animals. Syverton and Berry suggested that small rodents, the gopher in particular, which they found susceptible in experiments, may be the reservoir of the disease. Ten Broeck suggested that birds may be the reservoirs. Several investigators have carried out experiments on the susceptibility of birds and animals to equine encephalomyelitis. Recently, Davis has demonstrated that the eastern virus remains in the circulating blood of birds for a period of three or four days. These birds rarely showed more than mild symptoms, and continued their feeding as though they were perfectly well. These findings suggest that birds may be the natural host of the disease, and from them may have been transmitted

in Massachusetts in 1938 to horses, which have no natural immunity to the disease. The recognition of the occurrence of the disease in man is most recent. Thus far all infections of man have occurred during outbreaks of the disease in horses, indicating that man may be in danger only when the virus is unusually prevalent, as evidenced by the outbreak among horses.

The Massachusetts Outbreak of Equine Encephalomyelitis.

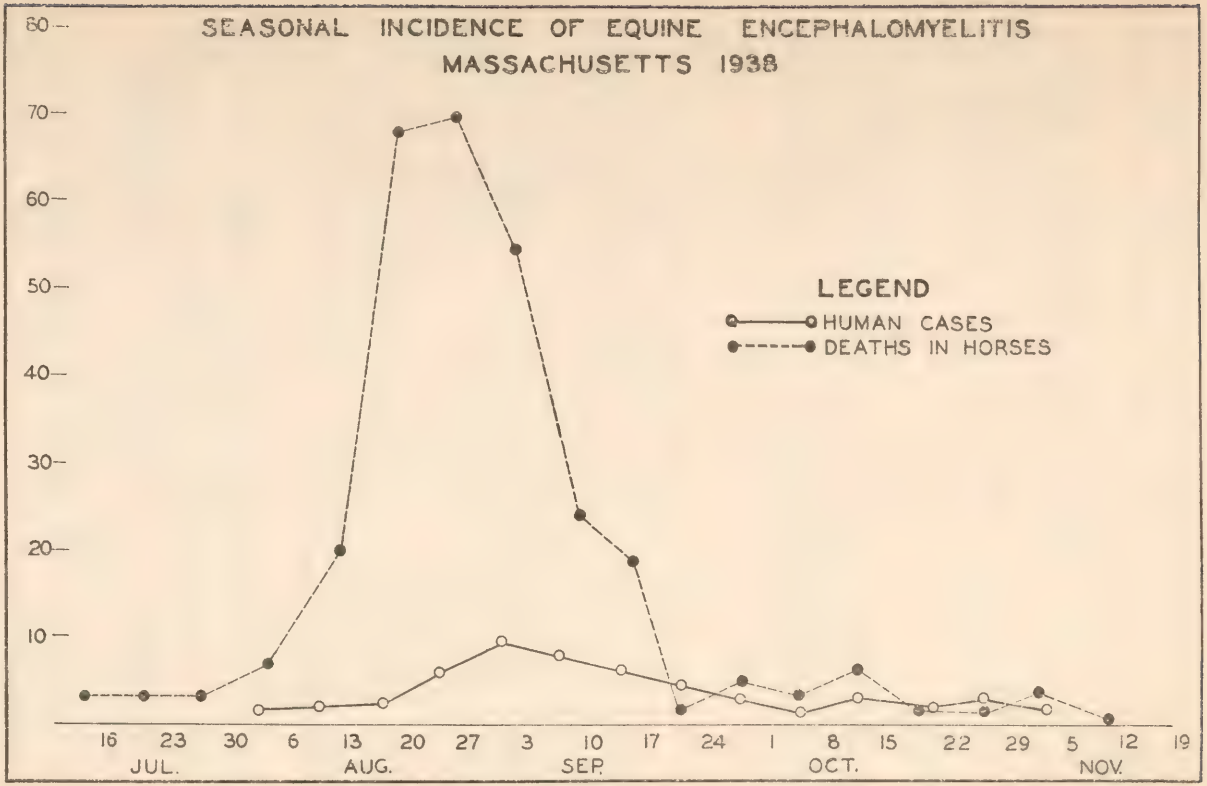
Epidemiology.

In July, 1938, for the first time recorded in the State, equine encephalomyelitis occurred among horses in Massachusetts. In the course of about ten weeks, 269 deaths were reported. The geographical distribution of deaths in horses and cases in humans is given in Map I. The disease made its first appearance in the basin of the Taunton River, which drains into near-by Rhode Island. The outbreak spread mainly in a northeasterly direction into the upper parts of the Taunton River drainage area. There were relatively few cases to the south and southeast and none on Cape Cod, which is separated from this area by Buzzards Bay and the Cape Cod Canal. The outbreak also spread northward to metropolitan Boston, and isolated cases occurred in a thirty mile square, extending from the mouth of the Taunton River in the south to Boston on the north, and from the boundary of Rhode Island, northeastward to the coast of Massachusetts. Rhode Island to the west reported 55 cases and Connecticut 29.


MAP I
DISTRIBUTION OF
EQUINE ENCEPHALOMYELITIS
MASSACHUSETTS
1938
LEGEND
▲—— CASES IN HUMANS
O —— DEATHS IN HORSES

During the summer and early autumn of 1938 rainfall in southeastern Massachusetts and Rhode Island was unusually heavy, and as a result mosquitoes were unusually prevalent in these areas. The prevailing winds in that region are from the southwest; and since the outbreak spread mainly in a northeasterly direction, it would seem that infectious mosquitoes may have been carried by these winds and may have widened the spread of the disease. Horses which were apparently well were moved from one country fair to another; in one such instance a horse was moved thirty miles from an area where the disease was prevalent to the northeast to a town near the coast. Although without symptoms when moved, the horse became ill on the following day and a diagnosis of equine encephalomyelitis was proved by the isolation of the virus from its brain. Thus the movement of infectious horses may have been a factor in the spread of the disease. During the outbreak, Fothergill and Dingle isolated the eastern virus from the brains of a pigeon that died in southeastern Massachusetts, and Tyzzer, Sellards and Bennett isolated the same virus from the brains of ring-necked pheasants from Connecticut. These findings suggested that birds may be the reservoirs of the disease and may be factors in its spread.

Almost simultaneously, in the same area, a new type of encephalitis appeared in man, particularly among children. Investigations by the Department of Public Health in cooperation with the Rockefeller Institute and Harvard Medical School revealed that human infections were due to the same virus causing disease in horses. The prevalence of the disease among horses and humans is given in Graph I. The median date of reported deaths among horses occurred during the week ending August 27, or two weeks in advance of the median date of onset for cases in humans. Apparently, the peak of the outbreak among horses preceded that of the outbreak among humans by an interval of over two weeks. Although the prevalence of the disease was much greater among horses than among humans, the rise and fall of the outbreak in these groups was the same. The outbreak among horses began slowly without increase


SEASONAL INCIDENCE OF EQUINE ENCEPHALOMYELITIS
MASSACHUSETTS 1938
LEGEND
HUMAN CASES
DEATHS IN HORSES
80
70
60
50
40
30
20
10
16 23 30 6 13 20 27 3 10 17 24 1 8 15 22 29 5 12 19
JUL. AUG. SEP. OCT. NOV.

Graph I.

for four weeks; and then rapidly reached its peak in two weeks. Remaining at this peak level for about a week, the outbreak subsided more slowly than it began. The last case was reported late in October, sixteen weeks after the beginning of the outbreak.

There were no multiple cases among families, and multiple cases on the same farm or in the same stable were rare among horses. These field observations confirmed experimental evidence that the disease is not transmitted by contact.

There were thirty-four human cases during the outbreak. Of this number, 25, or 73 per cent, proved fatal. This indicates the seriousness of the disease is that few of those affected recover, although it is not likely that the number of cases will ever assume large proportions.

Other Mosquito-Borne Diseases.

Although equine encephalomyelitis and malaria are the two most important mosquito-borne diseases which have occurred in Massachusetts, there are certain other diseases, some of which are, and some of which are suspected of being, mosquito-borne and which either occur or may occur in this State. These diseases have been placed in three groups in Table II. All of them have occurred in the United States, and are therefore considered as possible invaders of Massachusetts. Equine encephalomyelitis is included for the sake of completeness.

Table II. — *Diseases with Proved and Suspected Mosquito Transmission in the United States.*

Proved Mosquito Transmission.	Laboratory Mosquito Transmission.	Suspected Mosquito Transmission.
Malaria.[1]	Equine encephalomyelitis.[1]	Poliomyelitis.[1]
Yellow fever.[2]	Lymphocytic choriomeningitis.[1]	St. Louis encephalitis.[3]
Dengue.[3]	– – –	– – –
Filariasis.[3]	– – –	– – –

[1] Currently present in Massachusetts.
[2] Formerly present in Massachusetts.
[3] Not known to be indigenous in Massachusetts.

Diseases with Proved Mosquito Transmission.

Malaria is the most widely distributed mosquito-borne disease in the world. It has caused more suffering and death than any other single insect-borne disease. There have been cases of malaria in Massachusetts from early colonial times, and it is apparent that there have been at least three epidemic waves of malaria in the State. Since 1890 malaria has continued to decrease, and during the past ten years only eleven reported cases were acquired inside of Massachusetts.

In colonial times yellow fever appeared in New England. It was brought to port cities by sailing vessels which came from areas in the tropics and subtropics, where yellow fever was endemic. The mosquito, *Aedes aegypti*, carrier of the disease, was able to survive on board these ships, breeding in water casks. Under favorable meteorological conditions and a temperature of over 72° F., *Aedes aegypti* were able to survive, breed and transmit the virus in northern climates until the arrival of colder weather. Yellow fever may reappear in Massachusetts only if infected *Aedes aegypti* are imported; if these mosquitoes breed in large enough numbers to be temporarily established; and if the infected mosquitoes bite people, who, in turn, become ill, and infect *Aedes aegypti*. However, the importation of yellow fever is highly improbable, not only because of the lack of breeding places on modern steamships, but chiefly because of the efforts of the United States Public Health Service, which quarantines all vessels and airplanes which come from areas where the disease is endemic, or takes such measures as to ensure the destruction of *Aedes aegypti* on board ships or planes.

Dengue has never been known to exist in Massachusetts, although it has spread in epidemic waves through several of the Southern States. Filariasis is, in the main, restricted to tropical and subtropical regions. However, indigenous cases have occurred in South Carolina. This disease has not shown any evidence of extending to neighboring areas, and the chance of this disease reaching Massachusetts is very small.

Diseases with Suspected Mosquito Transmission.

Observations in Massachusetts indicate that there is no correlation between the prevalence of mosquitoes and the existence of poliomyelitis. Evidence supports the theory that poliomyelitis is not transmitted by mosquitoes. To date, St. Louis encephalitis has not been reported in Massachusetts. However, its recognition in such widely separated areas as Indiana and California indicates that the disease has involved hitherto unsuspected areas. The problem of mosquito transmission of St. Louis encephalitis remains unsolved. Further investigation must determine the rôle of the mosquito in this disease. Its seasonal distribution and the epidemiological observation indicate that St. Louis encephalitis may be mosquito-borne.

The Control of Mosquito-Borne Diseases.

The control of any mosquito-borne disease is based on one or more of the following procedures:

I. Control of the mosquito vector.
II. Protection of man and animal from the bite of infected mosquitoes.
III. Immunization of susceptibles.
IV. Removal of sources of infection of mosquito vectors by
    (*a*) Isolation of cases.
    (*b*) Treatment of carriers.
V. Prevention of entry of the mosquito vector and possible sources of infection into areas as yet unaffected by the disease.

All these methods are not applicable to every mosquito-borne disease. The decision as to which methods are to be employed must be based on an intimate knowledge of the disease in question and the habits and prevalence of the mosquito-carrier of the disease.

Certain conditions are necessary before a mosquito-borne disease can become prevalent in any area. One of these conditions is the existence of a certain numerical relationship between the hosts, vectors and susceptibles. When this numerical relationship becomes upset by a reduction of the number of vectors, the disease ceases to be epidemic and rapidly declines.

The life history and habits of mosquitoes are such that control measures may be designed to eliminate or control either the larvae or the adults. The measures which are most effective in any area depend upon the local factors and upon the genus and species of any mosquitoes concerned. It is impractical and uneconomical to attempt to control all mosquitoes. The control measures must be directed against that species which it is desired to reduce below the critical level.

Mosquito control has been effective in malaria and yellow fever. There has been considerably less experience in the effectiveness of this method in dengue, but since the principal vector of this disease is the same as for yellow fever, there is every reason to believe that mosquito control will prove just as effective. Protection from the bites of mosquitoes can be accomplished only under very limited conditions. Screening and avoidance of unnecessary exposure are the methods most effective. Spraying in houses, the application of mosquito repellants and swatting of adults are adjuvants. Specific immunization appears to be of value in yellow fever. In equine encephalomyelitis a vaccine produced from formolized virus grown in chick embryos has proved effective in the protection of horses. As yet, this vaccine is not applicable to man, except for laboratory workers, due to severe reactions which have been encountered. Moreover, the risk of exposure to the disease has been so small that community immunization has not been indicated. Vaccination of horses must be repeated annually, as immunity is temporary. Mohler attributes the decreased incidence of this disease in 1939, in part, to the vaccination of horses.

Malaria and filariasis are often spread by infected persons who are not known to have the disease. In modern civilization and rapid transportation it is practically impossible to eliminate the travel of such individuals. In summary it may be said that when control methods are dependent upon control of man, only limited success may be expected, as some individuals are unco-operative. The most effective method in the control of mosquito-borne dis-

eases has been the reduction of vectors to below the critical level. The choice as to what method is to be used in the control of a disease depends upon the peculiarities of that disease, and upon the available means for carrying out the necessary procedures.

Personnel and Methods.

In addition to the co-operation of the Work Projects Administration, various Federal, state and private organizations participated in the activities of the survey. Exclusive of the technical director and the entomologists, the regular personnel of the survey were all Work Projects Administration employees.

As it was desired to make regular periodic collections at prescribed points throughout the Commonwealth, such places as were thought likely to be permanent collection points were marked on topographical maps. A collection point was defined as an area 100 yards in radius about some permanent landmark as a center. Such a collection point may have been in the woods, meadow or at the edge of a large pond. In the last instance the center chosen was a prominent, easily identified landmark on the shore, and the collection point area extended 100 yards in either direction along the shore and 100 yards inland.

During the first two weeks of the survey, while the field personnel was being trained, collections were small in number. Collections were started on a state-wide basis during the first week of July. Toward the end of July the crews were familiar with their districts, and collection points were established in most of the towns. By the end of July, with few exceptions, collections were being made from most of the towns in the Commonwealth. Thereafter the number of collections continued to increase and reached a maximum late in September. The months of May, June and July, 1939, were exceptionally dry. The normal rainfall for these months is 10.25 inches. In 1939 only 6.53 inches of rain fell during the period, or about two thirds of the normal. Many marshes, small ponds and streams dried up, others decreased in size, and puddles and small collections of water were practically non-existent.

This lack of rainfall was reflected in the diminution in the number of mosquitoes. In 1938 mosquitoes were unusually prevalent, due to the heavy rainfall throughout the summer and early autumn and the flood in many river valleys in July; in 1939 mosquitoes were comparatively scarce. Although there are no established data on the prevalence of mosquitoes in 1938, the observations of mosquito control personnel may be taken as a measure. These workers, as well as residents, observed that during 1938 mosquitoes were unusually prevalent throughout Massachusetts. In 1939, on the other hand, mosquitoes were so scarce that vacationists reported they were able to sleep in the open without screens or netting.

Because of these meteorological conditions in 1939, collections of mosquitoes were quite difficult during July. Due to the fact that many ponds, marshes and streams practically dried up, new collection points had to be established. In August increased rainfall was reflected in the increased prevalence of mosquitoes. The number of collections in August increased, and in September reached a maximum. However, there was not enough rain to compensate for the three preceding dry months, and water collections began to decrease again in size and number. At no time during the summer and autumn of 1939 was there a normal prevalence of mosquitoes.

At the beginning of the survey identifications were based upon Tulloch's key, which was published in 1930. When about one hundred thousand specimens had been identified, enough data were collected to revise this key, and, as one of the objectives of the survey, a new key was used throughout the remainder of the project. It is adaptable to use in New England and perhaps in New York as well.

In a survey of this type only a relatively small sample of the entire mosquito population can be studied. Therefore, in order to be in a position to generalize about the whole, the sample has to be representative of the population. In this survey the selection of samples has been carefully avoided.

For the purpose of this analysis, a mosquito collection is defined as the finding of either one or more adults or one

or more larvae of one species of mosquitoes in one location. If, in a single sample, there are more than one species of larvae, this sample is counted as a separate collection for each of the species represented. By definition, it is impossible to have both adults and larvae in the same collection, as the former are collected from a different location than the latter. Of the total (47,232) collections of biting mosquitoes, 83.1 per cent, or 39,254 collections were larvae. The proportion of adults to larvae varied in the various counties. In Barnstable County adult collections were the largest, both in number and in per cent, representing 32.5 per cent of the total in that county. In Hampshire County, adult collections comprised only 5.3 per cent of the total.

TABLE III. — *Summary of Mosquito Collections, 1939.*

COUNTY.	Adults.	Larvae.	Total.
Barnstable	1,371	2,843	4,214
Berkshire	466	4,312	4,778
Bristol	202	1,842	2,044
Dukes and Nantucket	614	1,546	2,160
Essex	1,024	3,644	4,668
Franklin	405	2,369	2,774
Hampden	209	2,976	3,185
Hampshire	84	1,488	1,572
Middlesex	1,195	6,109	7,304
Norfolk	457	2,441	2,898
Plymouth	803	3,818	4,621
Suffolk	155	382	537
Worcester	993	5,484	6,477
Total	7,978	39,254	47,232

The number of collections as determined by punch card analysis is summarized in Table IV. The totals for adults and larvae and the per cent distribution of each are given by weeks. There was a peak in the number of adults during the weeks of June 11 to the 24th, inclusive, and a gradual decline thereafter throughout the duration of the survey. The explanation for this distribution of the adult collections rests on the fact that, subsequent to the week

of July 9 to 15, there was a disproportionate increase in the number of larvae, due to improved breeding conditions, and hence adults formed a relatively smaller proportion as more larvae were collected.

Collections per Square Mile.

The plan of the survey was made on the basis of the city or town constituting the area unit. The number of collections per square mile varied from community to community. Collections were made in all the cities and towns except two. The number of collections per square mile averaged 9 (8.93). Those communities in which the headquarters of the crews were located invariably had larger collections — in some cases 30 or more per square mile. The response of volunteer collectors varied greatly in different communities, and was responsible for unusually high coverage in the communities of Brookline and those in Barnstable County, where a large proportion of the collections was made by mosquito control workers. Lastly, it must be borne in mind that the towns vary greatly in area. This is a factor which cannot be practically evaluated. When a community was large, attempts were made to increase proportionately the amount of time devoted to collecting each week.

TABLE IV. — *Mosquito Collections — Adults, Larvae and Per Cent Distribution.*

[By weeks.]

Week ending —	Number of Collections.			Per Cent of Distribution.	
	Adults.	Larvae.	Total.	Adults.	Larvae.
April 22	0	40	40	0	100.0
April 29	0	40	40	0	100.0
May 6	1	22	23	4.3	95.7
May 13	0	32	32	0	100.0
May 20	1	22	23	4.3	95.7
May 27	1	20	21	4.8	95.2
June 3	2	28	30	6.7	93.3
June 10	11	31	42	26.2	73.8
June 17	65	31	96	67.7	32.3

TABLE IV. — *Mosquito Collections — Adults, Larvae and Per Cent Distribution* — Concluded.

[By weeks.]

Week ending —	Number of Collections.			Per Cent of Distribution.	
	Adults.	Larvae.	Total.	Adults.	Larvae.
June 24	186[1]	83	269	69.1	30.9
July 1	191	127	318	60.0	40.0
July 8	296	249	545	54.3	45.7
July 15	512	441	953	53.7	46.3
July 22	394	804	1,198	32.9	67.1
July 29	515	1,002	1,517	34.0	66.0
Aug. 5	460	1,500	1,960	23.5	76.5
Aug. 12	553	2,102	2,655	20.8	79.2
Aug. 19	585	2,342	2,927	20.0	80.0
Aug. 26	548	3,083	3,631	15.1	84.9
Sept. 2	353	3,457	3,810	9.3	90.7
Sept. 9	381	3,705	4,086	9.3	90.7
Sept. 16	588	4,091	4,679	12.6	87.4
Sept. 23	902	4,261	5,163	17.5	82.5
Sept. 30	839	4,441	5,280	15.9	84.1
Oct. 7	608	4,791	5,399	11.3	88.7
Oct. 14	365	2,582	2,947	12.4	87.6
Oct. 21	126	1,603	1,729	7.3	92.7
Oct. 28	42[2]	461	503	8.3	91.7
Nov. 4	0	130	130	0	100.0
Nov. 11	3	87	90	3.3	96.7
Nov. 18	1	35	36	2.8	97.2
Nov. 25	4	32	36	11.1	88.9
Dec. 2	0	32	32	0	100.0
Dec. 9	1	32	33	3.0	97.0
Dec. 16	0	17	17	0	100.0
Total	8,534	41,756	50,290[3]	17.0	83.0

[1] Collections prior to June 24 were made by departmental personnel and volunteers.

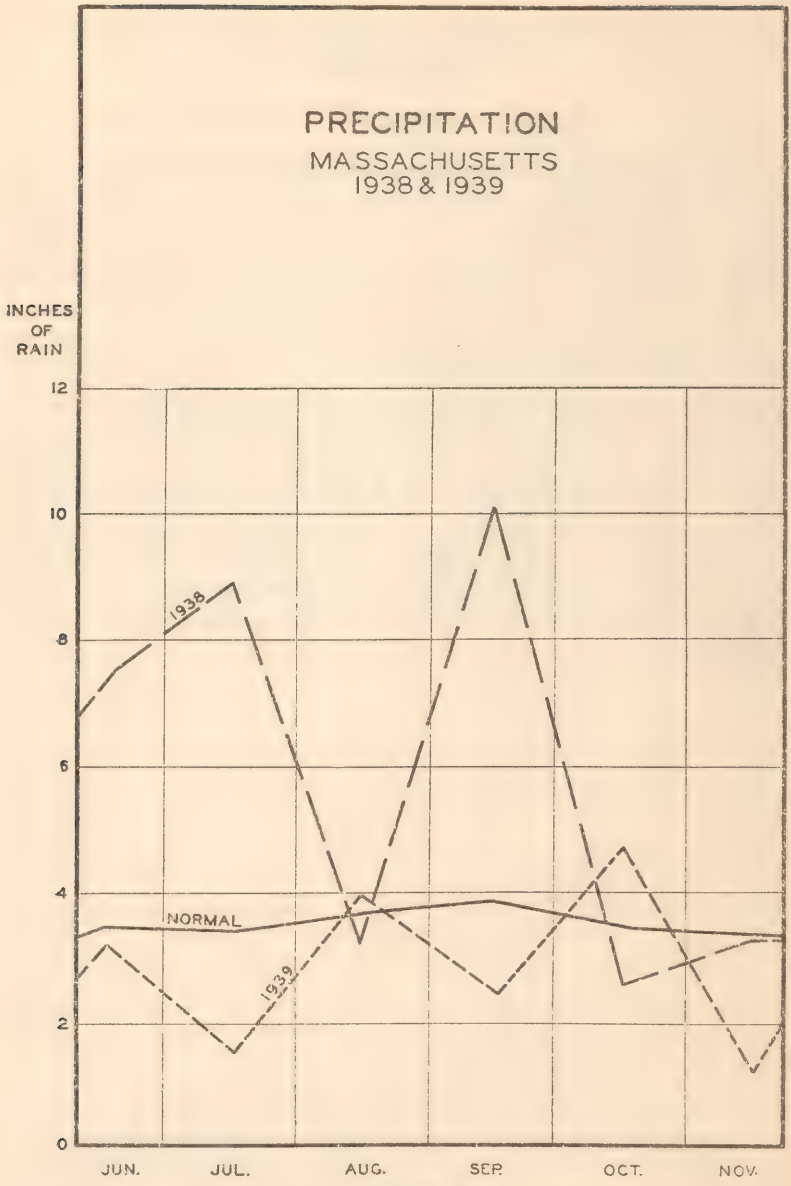
[2] Collections after October 28 were largely on Martha's Vineyard, where the season is late. A few scattered collections were made by volunteers.

[3] These figures were obtained from the punch card analysis by interpolation from serial grouping. The actual total was 47,232.

Influence of Meteorological Conditions on Mosquitoes.

Rain.

It was confirmed by field observations that there is an increase in mosquito breeding after heavy rains. However, the ponds and streams were so low in the summer of 1939 that many remained below normal levels throughout the season. The association of rain and mosquitoes becomes more apparent on comparison of the 1938 and 1939 precipitation data. During 1938 there was an accumulation of 11.7 inches of rain above normal, an excess of 26 per cent. That year mosquitoes were unusually prevalent throughout the State. In 1939 there was a deficit of 5.5 inches of rain, 13 per cent below normal. Mosquitoes were at no time as prevalent as in other years. The 1938 rainfall was far above normal in June, July and September; in 1939 rainfall was below normal during the mosquito season. (See Graph II.)


PRECIPITATION
MASSACHUSETTS
1938 & 1939
INCHES OF RAIN
12
10
8
6
4
2
0
1938
NORMAL
1939
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.

Graph II.

Temperature.

During 1939 the temperature showed little deviation from normal. A deficit in Fahrenheit degree-days developed in April and remained unchanged through July. In August an excess accumulated which lasted through October. Warm weather is conducive to increased mosquito breeding. However, the slight excess which accumulated at the end of the summer had little effect because of the lack of standing water. Again we contrast 1939 with 1938, and find that 1938 was a more favorable year for mosquitoes. The summer of 1938 was not only wetter but warmer, and mosquito breedimg conditicns were nearer the optimum.

Wind.

Adult mosquitoes, when borne by winds, will be disseminated over a large area in the direction taken by the wind. The direction of prevailing winds for the towns in which collections were made by the Standard United States Weather Bureau Method. Table V lists the direction of the prevailing winds in the towns in which collections were made:

TABLE V. — *Direction of Prevailing Winds.*

Week ending —	Direction.	Week ending —	Direction.
July 1	SW	Sept. 2	W
July 8	SW	Sept. 9	SW
July 15	SW	Sept. 16	SW
July 22	SW	Sept. 23	SW
July 29	SW	Sept. 30	SW
Aug. 5	W	Oct. 7	NW
Aug. 12	W	Oct. 14	NW
Aug. 19	W	Oct. 21	NW
Aug. 26	W	Oct. 28	NW

As the prevailing winds throughout the middle and early parts of the summer are from the west and southwest, the carrying of mosquitoes by the wind is chiefly to the east and northeast. Salt marsh mosquitoes were therefore carried in a northeasterly direction. In those areas of the State

which are northeast of salt water, adults of salt marsh mosquitoes may be expected to be found farther inland than where salt water is to the northeast. The dissemination of a mosquito-borne disease would be more extensive in the direction taken by the prevailing winds.

Mosquito Breeding Places.

Table VI was compiled by punch card analysis from the data recorded in these surveys. Samples were not taken from identical sources in an area less than 100 yards in radius. There were twenty different types of breeding

Table VI. — *Mosquito Breeding Places at Regular Collection Points.*

Type of Breeding Places.	Number of Breeding Places.	Number of Species Collected.	Number of Collections.[1]	Average Number of Collections Per Breeding Place.
1. Artificial pool	46	7	435	9.5
2. Barrel	82	10	789	9.6
3. Bird bath, flower pot	6	4	63	10.5
4. Cesspool or overflow	14	7	128	9.1
5. Cistern	9	5	62	6.9
6. Dump	92	13	1,064	11.6
7. Watering trough	27	9	273	10.1
8. Cranberry bog	88	18	1,352	15.4
9. Excavation	19	11	185	9.7
10. Quarry	2	5	27	13.5
11. Sand pit	7	6	47	6.7
12. Root hole	22	9	175	7.9
13. Tree hole	15	8	187	12.5
14. Well	13	11	169	13.0
15. Marsh or swamp	637	15	7,781	12.2
16. Pond or lake	468	15	5,025	10.7
17. Puddle	110	14	1,012	9.2
18. River or stream	1,173	17	10,519	9.0
19. Rocky crevice	9	8	69	7.6
20. Running and still water combined	382	18	3,805	9.9
Total	3,221	–	33,167	10.3

[1] Does not include specimens collected by volunteers.

places included in our analysis. Streams, marshes, swamps, ponds and lakes were most frequent. Dumps and barrels were the two most common man-made breeding places.

Lastly, not all species were found in the same collection point. Certain species were found in the same water collection with a greater frequency than others. The association of certain vectors of equine encephalomyelitis with other species are summarized in Table VII. *Aedes atropalpus* was found to be most frequently associated with *Culex pipiens*. All other vectors were associated with *Culex apicalis* and *Culex pipiens* to about the same degree. It is to be noted that these associations are between species collected in a collection point 100 yards in diameter throughout the entire season. The species may not have been collected at the same time nor from the same water collection. However, in the majority of the cases there was only one water body at a collection point, and therefore the associations hold as to place better than as to time.

There is very little positive association between the various salt marsh mosquitoes. This observation may be explained in part by the fact that *Aedes cantator* may breed in water containing less salt than that in which *Aedes sollicitans* breed. The fresh water *Aedes* vectors are significantly associated with *Culex territans* which was collected in much smaller numbers than other species of *Culex*.

In all these tables only a few attempts have been made to interpret the data. Too many factors are concerned in the ecology and bionomics of mosquitoes to assign any one observation to a peculiar circumstance without due consideration of all other factors.

TABLE VII. — *Association of Larvae at Collection Points.*[1]

NUMBER OF COLLECTIONS.

SPECIES.	AEDES.				
	Atropalpus.	Cantator.	Sollicitans.	Triseriatus.	Vexans.
Aedes atropalpus	–	–	–	–	41
A. canadensis	–	12	1	–	5
A. cantator	–	–	50	1	80
A. cinereus	–	15	4	–	31
A. excrucians	–	–	–	–	3
A. fitchii	–	–	–	–	–
A. intrudens	1	–	–	–	3
A. sollicitans	–	83	–	–	–
A. stimulans	–	–	–	–	–
A. taeniorhynchus	–	15	16	–	–
A. triseriatus	–	1	–	–	2
A. vexans	13	45	11	2	–
Anopheles punctipennis	30	13	5	10	382
A. quadrimaculatus	2	9	14	–	82
Culex apicalis	34	449	123	43	1,088
C. pipiens	89	368	135	43	844
C. salinarius	3	215	91	–	109
C. territans	47	63	15	42	438
Theobaldia melanura	–	47	8	1	42
T. morsitans	–	–	–	–	1
Total	219	1,335	476	142	3,152

[1] Number of collections of larvae of other species at collection points where certain vectors were found some time during the season.

TABLE VII. — *Association of Larvae at Collection Points*[1] — Concluded.

PER CENT OF COLLECTIONS.

SPECIES.	AEDES.				
	Atropalpus.	Cantator.	Sollicitans.	Triseriatus.	Vexans.
Aedes atropalpus	–	–	–	–	1.3
A. canadensis	–	.9	.1	–	.2
A. cantator	–	–	10.5	.7	2.5
A. cinereus	–	1.1	.8	–	1.0
A. excrucians	–	–	–	–	.1
A. fitchii	–	–	–	–	–
A. intrudens	.5	–	–	–	.1
A. sollicitans	–	6.2	–	–	–
A. stimulans	–	–	–	–	–
A. taeniorhynchus	–	1.1	3.4	–	–
A. triseriatus	–	.1	–	–	.1
A. vexans	5.9	3.4	2.3	1.4	–
Anopheles punctipennis	13.7	1.0	1.7	7.0	12.1
A. quadrimaculatus	.9	.7	2.9	–	2.6
Culex apicalis	15.5	33.6	25.8	30.3	34.5
C. pipiens	40.6	27.6	28.4	30.3	26.8
C. salinarius	1.4	16.1	19.1	–	3.5
C. territans	21.5	4.7	3.2	29.6	13.9
Theobaldia melanura	–	3.5	1.7	.7	1.3
T. morsitans	–	–	–	–	–
Total	100.0	100.0	100.0	100.0	100.0

[1] Number of collections of larvae of other species at collection points where certain vectors were found some time during the season.

The Collection of Adult Mosquitoes.

Adult mosquitoes were collected by two methods. The most important of these was the capture of specimens by the killing tube, which was placed directly over the resting mosquito. The second method was sweeping with nets. As the collectors were novices in using the net, and since some experience is required in its manipulation, this method was less productive than the former. There were 23,484 specimens in 7,978 collections. Adults represented 16.9 per cent of the total collections. Although 75 per cent or more of the adults were collected by the personnel of the survey, and hence represented collections of those adults with diurnal habits, the remainder of the collections were made by volunteers and contain a higher proportion of mosquitoes with nocturnal habits.

Biting Habits.

These data are summarized in the following series of tables. In Table VIII are listed those mosquitoes which were collected by placing the killing tube over a mosquito which was resting on a person's body. Although the mosquito may not have been biting, it presumably was attracted to man in the anticipation of obtaining blood. *Aedes sollicitans* is the most numerous offender. *Mansonia perturbans* is a ferocious biter, but ceases to be a nuisance about the time that the disease may be expected to increase in prevalence. *Aedes sollicitans* was more numerous towards the middle and end of the mosquito season. *Aedes cantator* and *Aedes vexans* were more prevalent during the middle of the season. These last three are vectors of equine encephalomyelitis and were the three most numerous biters.

There was much variation in the relative percentages of the mosquitoes which were collected inside houses and those which were collected on man. Those which were collected inside houses were contributed by volunteers who were interested in finding out what mosquitoes interrupted their slumbers. Those in Table IX, therefore, represent mosquitoes with greater nocturnal biting habits as contrasted

TABLE VIII. — *Adult Mosquitoes Caught on Man.*

SPECIES.	Number of Specimens.	Per Cent.
Aedes sollicitans	738	37.3
Mansonia perturbans	511	25.8
Aedes cantator	311	15.7
Aedes vexans	120	6.0
Aedes aurifer	52	2.6
Aedes canadensis	50	2.5
Aedes cinereus	47	2.4
Culex pipiens	42	2.1
Aedes excrucians	20	1.1
Aedes intrudens	19	0.9
Culex salinarius	14	0.7
Aedes taeniorhynchus	12	0.6
Culex territans	10	0.5
Anopheles punctipennis	7	0.4
Culex apicalis	6	0.3
Aedes fitchii	4	0.2
Aedes triseriatus	3	0.2
Theobaldia melanura	3	0.2
Aedes species unidentified	3	0.2
Aedes stimulans	2	0.1
Anopheles quadrimaculatus	2	0.1
Aedes dorsalis	1	0.0
Total	1,977	99.9

with those in Table VIII, where diurnal activity predominated. *Culex pipiens* and *Mansonia perturbans* are the most frequent invaders. *Anopheles quadrimaculatus*, the malaria vector, is third. *Culex apicalis*, which is described as a biter of cold-blooded animals, was fourth in this series. The *Aedes* mosquitoes were infrequent invaders of homes, and were not a serious menace inside buildings. This observation indicates that the greatest danger from vectors of equine encephalomyelitis is outdoors.

In evaluating the data above, it is necessary to point out that all mosquitoes do not enter houses with the intent to bite. Although most mosquitoes are attracted indoors with

the prospect of a blood meal, some species, such as *Culex apicalis*, enter buildings principally to hibernate. With the approach of cold weather mosquitoes are more likely to seek warm winter quarters. When the mosquitoes caught in houses are added to those which are caught on man, a better index of the biting mosquitoes can be obtained. These data are compiled in Table X.

TABLE IX. — *Adult Mosquitoes Caught in Houses.*

SPECIES.	Number of Specimens.	Per Cent.
Culex pipiens	973	31.1
Mansonia perturbans	911	29.1
Anopheles quadrimaculatus	407	13.0
Culex apicalis	189	6.0
Culex territans	165	5.3
Culex salinarius	85	2.7
Aedes cantator	56	1.8
Aedes sollicitans	56	1.8
Anopheles punctipennis	46	1.5
Aedes vexans	44	1.4
Anopheles maculipennis	27	.9
Culex species unidentified	26	.8
Anopheles walkeri	23	.7
Aedes triseriatus	19	.6
Aedes canadensis	17	.5
Theobaldia melanura	14	.4
Aedes atropalpus	12	.4
Aedes excrucians	12	.4
Aedes aurifer	11	.3
Aedes cinereus	10	.3
Aedes trivittatus	9	.3
Aedes fitchii	6	.2
Aedes intrudens	3	.1
Aedes species unidentified	3	.1
Chaoborinae species unidentified	3	.1
Aedes stimulans	1	0.0
Aedes punctor	1	0.0
Theobaldia morsitans	1	0.0
Total	3,130	99.8

TABLE X. — *Adult Mosquitoes Caught on Man and in Houses.*

SPECIES.	Number of Specimens.	Per Cent.
Mansonia perturbans	1,422	27.8
Culex pipiens	1,015	19.8
Aedes sollicitans	794	15.5
Anopheles quadrimaculatus	409	8.0
Aedes cantator	367	7.1
Culex apicalis	195	3.8
Culex territans	175	3.4
Aedes vexans	164	3.2
Culex salinarius	99	1.9
Aedes canadensis	67	1.3
Aedes aurifer	63	1.2
Aedes cinereus	57	1.1
Anopheles punctipennis	53	1.0
Aedes excrucians	32	.6
Anopheles maculipennis	27	.5
Culex species unidentified	26	.5
Anopheles walkeri	23	.5
Aedes triseriatus	22	.4
Aedes intrudens	22	.4
Theobaldia melanura	17	.3
Aedes atropalpus	12	.2
Aedes taeniorhynchus	12	.2
Aedes fitchii	10	.2
Aedes trivittatus	9	.2
Aedes species unidentified	6	.1
Chaoborinae species unidentified	3	.1
Aedes stimulans	3	.1
Aedes dorsalis	1	0.0
Aedes punctor	1	0.0
Theobaldia morsitans	1	0.0
	5,107	99.4

Here the species are rearranged as to their numerical importance: *Mansonia perturbans* heads the list, *Culex pipiens* is second, *Aedes sollicitans* is third, and *Anopheles quadrimaculatus*, fourth. Among the species captured in

houses, the vectors of equine encephalomyelitis represent about one fourth of the total number of specimens.

Table XI lists the mosquitoes caught in barns and stables. Presumably, the main attraction was the prospect of a blood meal. Here, however, the blood was not from man, but from horses, cattle and other domestic animals. A second urge which became effective with the onset of cold weather was the seeking of a warm place in which to hibernate. *Culex pipiens* was by far the most frequent invader of the barn and stable. *Mansonia perturbans* was the second in numerical importance, and *Aedes vexans*, third. *Aedes sollicitans*, which is a ferocious biter of man, was caught only once inside a barn or stable.

TABLE XI. — *Adult Mosquitoes Caught in Barn and Stable.*

SPECIES.	Number of Specimens.	Per Cent.
Culex pipiens	98	46.4
Mansonia perturbans	35	16.6
Aedes vexans	18	8.5
Aedes cantator	14	6.6
Culex salinarius	13	6.2
Culex apicalis	8	3.8
Anopheles quadrimaculatus	4	1.9
Culex territans	4	1.9
Culex species unidentified	4	1.9
Aedes cinereus	3	1.4
Aedes excrucians	3	1.4
Anopheles punctipennis	3	1.4
Aedes atropalpus	1	.5
Aedes fitchii	1	.5
Aedes sollicitans	1	.5
Aedes stimulans	1	.5
Total	211	100.0

Environment.

The collection of those species of adult mosquitoes which are of public health importance in different types of terrain is summarized in Table XII. These data are based on

adults caught at regular collection points. It is to be expected that collections were made more often in certain types of terrain in preference to others. Cultivated fields were seldom trespassed upon, and hence only a few collections were made here. The description of the collection point area as given in this table is the chief character of the land included in the 100-yard radius of the collection point. In many instances other types of terrain were also present, but represented only a small portion of the collection point area. The totals on the left of Table XII furnish a base against which the species data can be compared. *Aedes cantator* and *Aedes sollicitans* were caught with about equal frequency in meadows and in woods. *Aedes vexans* was captured most frequently in the woods. The preference of this mosquito for the woods is an important factor in any control-program that may be instituted against equine encephalomyelitis. Horses should be removed from pastures that are in close proximity to woods, and people should refrain from entering woods during outbreaks of this disease. In this way exposure to *Aedes vexans*, which may be infectious, will be greatly reduced.

In applying the data collected by this survey, it seems apparent that perhaps one half of the exposures to *Aedes vexans* would be eliminated simply by keeping away from the woods. These facts seem to apply to *Aedes triseriatus* and to *Anopheles quadrimaculatus*, the principal vector of malaria; however, the number of collections in both these instances is smaller and statistically this conclusion is less certain. *Aedes atropalpus* and *Aedes taeniorhynchus* were captured in too small a number to permit any significant inference.

TABLE XII. — *Association of Vector Adults with Different Types of Terrain.*

NUMBER OF COLLECTIONS.

NATURE OF TERRAIN.	AEDES.						ANOPHELES.	Totals.
	Atropalpus.	Cantator.	Sollicitans.	Taeniorhynchus.	Triseriatus.	Vexans.	Quadrimaculatus.	
Cultivated fields	–	7	10	–	–	7	3	27
Meadow — pastured	–	11	32	1	4	1	2	51
Meadow — unpastured	–	102	177	8	2	16	10	315
Rocky	–	–	–	–	–	1	3	4
Woods	–	67	92	3	16	56	14	248
Meadow and woods	–	70	99	1	5	24	5	204
Meadows and cultivated fields	1	11	20	–	2	4	2	40
Total	1	268	430	13	29	109	39	889

PER CENT OF COLLECTIONS.

Cultivated fields	–	2.6	2.6	–	–	6.4	7.7	3.0
Meadow — pastured	–	4.1	7.4	7.7	13.8	0.9	5.1	5.7
Meadow — unpastured	–	38.1	41.1	61.5	6.8	14.6	25.6	35.5
Rocky	–	–	–	–	–	.9	7.7	.4
Woods	–	25.0	21.3	23.1	55.5	51.3	35.9	27.9
Meadow and woods	–	26.1	23 1	7.7	17.2	22.0	12.8	23.0
Meadows and cultivated fields	100	4.1	4.6	–	6.8	3.7	5.1	4.5
Total	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Vectors of Equine Encephalomyelitis.

Numerical Importance of Vectors.

There are six mosquitoes in Massachusetts which have been demonstrated in the laboratory to transmit the eastern virus. These are all *Aedes* mosquitoes. Their numerical importance in relation to other species, both vectors and non-vectors, is discussed in this section. The geographical and seasonal distribution, the life habits, and public health importance of such species are discussed in a later section.

Table XIII. — *Numerical Importance of Vectors of Equine Encephalomyelitis, by Specimens.*

Species.	Adults.		Larvae.		Specimens.	Numerical Importance in Per Cent.
	Number.	Per Cent.	Number.	Per Cent.		
Aedes atropalpus	60	5.7	993	94.3	1,053	7.8
A. cantator	1,329	33.0	2,701	67.0	4,030	29.7
A. sollicitans	2,548	70.7	1,054	29.3	3,602	26.6
A. taeniorhynchus	20	15.2	112	84.8	132	1.0
A. triseriatus	228	71.3	92	29.7	320	2.4
A. vexans	1,052	24.0	3,358	76.0	4,410	32.5
Total	5,237	38.7	8,310	61.3	13,547	100.0

In Table XIII the vectors are evaluated on the basis of the number of specimens collected. *A. vexans* was the most numerous, *A. cantator* and *A. sollicitans* were second and third, respectively, in numerical importance. The other three vectors were far below these in numbers. The per cent of adult specimens was highest in *A. sollicitans* and in *A. triseriatus;* the latter, however, was caught in much smaller numbers.

The number of vectors collected varied from one section of the State to another. Collections of larvae and adults combined are tabulated by counties in Table XIV. *A. atropalpus* larvae were collected in five counties, three in the Connecticut River Valley, one in the northeastern part

of the State, and one on Cape Cod. *A. cantator* and *A. sollicitans* were collected only in the counties along the coast, and *A. taeniorhynchus* only in Dukes County. *A. triseriatus* was collected in small numbers in most of the counties. *A. vexans* was the most numerous species and was collected in all counties. Of the specimens collected in Dukes and Nantucket counties, 23.2 per cent were vectors, and of those collected in Barnstable County 13.7 per cent were vectors. Equine encephalomyelitis, however, has not been reported from these areas. In the remainder of the counties there was no significant difference in the per cent of larvae of vector species.

Considering adult specimens only, the per cent which were vectors varied more markedly from county to county. Table XV summarizes these data. *A. atropalpus* adults were collected in small numbers in the Connecticut River Valley and in northeastern Massachusetts and on Cape Cod. *A. cantator* and *A. sollicitans* adults were collected in the coastal regions, and, occasionally, further inland. *A. triseriatus* and *A. vexans* adults were captured in all counties, the latter being found in far greater numbers. In Dukes and Nantucket counties 76.3 per cent of the adult specimens were vectors. This figure is much higher than elsewhere in the State. In Essex and Barnstable counties the vectors represented 30.8 per cent and 27.9 per cent, respectively. Bristol County vectors made up 15.3 per cent of the adult specimens. Vectors comprised 9.6 per cent to 21.8 per cent in Franklin, Hampden, Hampshire, Norfolk and Suffolk counties. In Berkshire, Middlesex and Worcester counties vectors comprised 3.9 per cent, 6.0 per cent and 6.5 per cent, respectively, a statistical significant difference.

TABLE XIV. — *Numerical Importance of Vectors, by counties.*

COMBINED TOTAL OF ADULTS AND LARVAE, MASSACHUSETTS, 1939.

COUNTY.	AEDES.						Total Vectors.	Total Aedes.	Per Cent Vectors.	Total All Genera.	Per Cent Vectors.
	Atropalpus.	Cantator.	Sollicitans.	Taeniorhynchus.	Triseriatus.	Vexans.					
Barnstable	12	1,780	1,198	0	7	1,751	4,748	6,561	72.4	34,653	13.7
Berkshire	0	0	0	0	45	341	386	447	86.2	25,948	1.5
Bristol	0	281	10	0	12	223	526	615	85.5	14,095	3.7
Dukes[1]	0	975	1,337	131	3	246	2,692	2,811	95.7	11,623	23.2
Essex	12	414	658	0	15	87	1,186	1,452	81.7	30,535	3.9
Franklin	183	0	0	0	46	192	421	471	89.3	12,724	3.3
Hampden	810	0	0	0	34	395	1,239	1,338	92.6	17,964	6.9
Hampshire	34	0	0	0	13	226	273	303	90 0	8,948	3.1
Middlesex	1	100	98	0	10	188	397	577	68.8	45,915	.9
Norfolk	0	159	140	0	58	66	423	902	46.9	16,210	2.6
Plymouth	0	291	126	1	9	411	838	1,316	63.7	18,663	4.5
Suffolk	0	30	35	0	10	11	86	118	72.9	5,459	1.6
Worcester	1	0	0	0	58	273	332	717	46.3	30,350	1.1
Total	1,053	4,030	3,602	132	320	4,410	13,547	17,628	76.8	273,087	5.0

[1] Including Nantucket.

TABLE XV. — *Vectors of Equine Encephalomyelitis — Per Cent of Adult Specimens which were Vectors.*

ADULT SPECIMENS.	AEDES.								Per Cent of Collections which were Vectors.
	Atropalpus.	Cantator.	Sollicitans.	Taeniorhynchus.	Triseriatus.	Vexans.	Vectors.	All Species.	
Barnstable	12	439	823	0	7	413	1,694	6,052	27.9
Berkshire	0	0	0	0	39	15	54	1,381	3.9
Bristol	0	33	8	0	2	54	97	632	15.3
Dukes and Nantucket	0	367	730	19	3	61	1,180	1,546	76.3
Essex	2	206	648	0	15	48	919	2,982	30.8
Franklin	35	0	0	0	40	35	110	583	18.9
Hampden	5	3	0	0	19	47	74	403	18.4
Hampshire	4	0	0	0	9	7	20	208	9.6
Middlesex	1	5	83	0	9	95	194	3,210	6.0
Norfolk	0	86	136	0	21	46	289	1,326	21.8
Plymouth	0	175	86	1	4	134	400	2,415	16.6
Suffolk	0	14	34	0	10	9	67	580	11.6
Worcester	1	0	0	0	50	88	139	2,166	16.5
Total	60	1,329	2,548	20	228	1,052	5,237	23,484	22.3

Biting Habits.

Table VIII, above, lists the adult mosquitoes captured on man. The vectors were represented as follows:

	Number.	Per Cent.
Aedes sollicitans	738	37.3
A. cantator	311	15.7
A. vexans	120	6.0
A. taeniorhynchus	12	0.7
A. triseriatus	3	0.2
A. atropalpus	0	0.0
Total vectors	1,184	59.9
Other aedes	198	10.0
All other genera	595	30.1
Total	1,977	100.0

Table IX, above, lists the adult mosquitoes caught in houses. Here the vectors were represented as follows:

	Number.	Per Cent.
Aedes cantator	56	1.8
A. sollicitans	56	1.8
A. vexans	44	1.4
A. triseriatus	19	0.6
A. atropalpus	12	0.4
A. taeniorhynchus	0	0.0
Total vectors	187	6.0
Other aedes	73	2.2
All other genera	2,870	91.8
Total	3,130	100.0

Of the 1,977 adults captured on man, 1,184, or 59.9 per cent, were vectors. Of the 3,130 adults caught in houses, only 187, or 6.0 per cent, were vectors. It has already been pointed out that the vast majority of the mosquitoes captured on man are collected outdoors. Therefore it is at once apparent that the chances of a vector biting man are

about ten times as great outdoors as indoors. This information is important in protecting animals and man from unnecessary exposure to vectors during the outbreaks of the disease. Measures should be directed toward the removal of horses and mules from pastures and into screened stables. Children and infants, as well as adults, should be kept behind screens as much as possible, and not permitted to remain unprotected when outdoors where mosquitoes are prevalent.

Unfortunately, the collections of mosquitoes on animals were so small that they are of no value. The 211 specimens which were captured in barns and stables may be an indication of the attraction of the vectors to horses and cattle. There were 33 vectors captured in barns; these were *A. vexans* 18, *A. cantator* 14 and *A. sollicitans* 1, forming 8.5 per cent, 6.6 per cent, 0.5 per cent of all mosquitoes captured in these buildings. These numbers are too small to be conclusive. If the situation is analogous to man, then we may assume that whereas only 15.5 per cent of the mosquitoes captured in barns and stables were vectors, the vectors comprise a much larger per cent of the mosquitoes which bite animals outdoors.

Vectors of Malaria.

Numerical Importance.

All of the *Anopheles* of Massachusetts may act as vectors of malaria. However, *A. quadrimaculatus* is the only important one. *A. maculipennis* may transmit the plasmodia with greater effectiveness than *A. punctipennis*, but the latter is much more numerous and hence may play a greater rôle. *A. crucians* and *A. walkeri* are rare and hence are of no importance. The collection data on these vectors are summarized in Table XVI:

TABLE XVI. — *Vectors of Malaria — Distribution of Species by Counties (Collections).*

[A. = Adults; L. = Larvae.]

COUNTY.	ANOPHELES.										TOTAL.	
	CRUCIANS.		MACULIPENNIS.		PUNCTIPENNIS.		QUADRIMACULATUS.		WALKERI.			
	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.
Barnstable	–	5	0	0	2	41	4	21	1	–	7	67
Berkshire	–	–	0	11	42	830	29	57	1	8	72	906
Bristol	–	–	1	2	12	244	11	152	1	2	25	400
Dukes and Nantucket	–	–	0	0	0	5	0	0	0	–	–	5
Essex	–	1	2	1	15	292	60	619	12	6	89	919
Franklin	–	–	–	4	16	544	2	28	0	1	18	577
Hampden	–	–	–	5	21	1,343	4	189	0	4	25	1,541
Hampshire	–	–	–	2	3	146	5	9	–	1	8	158
Middlesex	–	–	–	4	22	448	14	178	–	3	36	633
Norfolk	–	–	–	2	2	129	20	117	2	2	24	250
Plymouth	–	1	–	5	5	392	14	241	4	–	23	639
Suffolk	–	–	–	–	2	3	1	2	–	–	3	5
Worcester	–	–	2	21	50	1,341	18	116	7	4	77	1,482
Total	0	7	5	57	192	5,758	182	1,729	28	31	407	7,582

The *Anopheles* comprised 16.9 per cent of the total collections, 19.3 per cent of the larvae, and 5.1 per cent of the adults. The largest numbers of collections of *Anopheles*, 1,541 and 1,482, were made, respectively, in Hampden and Worcester counties. Since Worcester is a much larger county than Hampden, the *Anopheles* were more prevalent in the latter county. Very few collections were made in Dukes, Nantucket and Suffolk Counties. The small number found in Suffolk County is easily explained because this county comprises the city of Boston and three other densely populated communities where mosquitoes are less likely to breed. Dukes and Nantucket Counties, on the other hand, are quite rural, and why *Anopheles* were collected in such small numbers has not been explained.

Biting Habits.

Anopheles were rarely captured on man outdoors. There were only 7 *A. punctipennis* and 2 *A. quadrimaculatus* among a total of 1,977 mosquitoes captured on man. It seems that these species are not serious offenders in the open. Of 3,130 mosquitoes captured in houses, *A. quadrimaculatus* comprised 13.0 per cent, *A. punctipennis* 1.5 per cent, *A. maculipennis* 0.9 per cent and *A. walkeri* 0.7 per cent, a total of 16.1 per cent. *Anopheles* prefer to bite man indoors, apparently. This observation may be contrasted with the *Aedes* vectors of equine encephalomyelitis where the situation is reversed. Of a total of 211 mosquitoes captured in barns and stables, 7 specimens (3.3 per cent) were *Anopheles*. Collections of mosquitoes on animals were not attempted. It is therefore impossible to say that *Anopheles* are not attracted to animals, but the larger proportion of specimens captured in houses indicate that *Anopheles* prefer to bite man.

Mosquitoes of Massachusetts.

Genera.

The order of *Diptera* is subdivided into a number of families; the particular family of flies to which all mosquitoes belong is termed *Culicidae*. This family is composed

of two subfamilies, the *Culicinae* and *Chaoborinae*. The members of the first subfamily are readily distinguished from the other by the presence in the female of a conspicuous proboscis adapted for bloodsucking. The *Culicinae*, or biting mosquitoes, are divided into two tribes, the *Anophelini* and the *Culicini*. The tribes, in turn, are divided into genera, and genera into species. The tribe *Anophelini* contains only one genus, the *Anopheles*. All the other genera of biting mosquitoes belong to the tribe *Culicini*. The name of a mosquito, as it is generally used, consists of the name of the genus and that of the species.

TABLE XVII. — *Relative Importance of the Genera of Massachusetts Mosquitoes — Per Cent of Adults and Larvae, by Specimens.*

GENUS.	ADULTS.		LARVAE.		Total Specimens.	Relative Importance by Per Cent.
	Number.	Per Cent.	Number.	Per Cent.		
Aedes	8,124	46.1	9,504	53.9	17,628	6.5
Anopheles	1,177	4.1	27,423	95.9	28,600	10.5
Culex	7,401	3.4	207,650	96.6	215,051	78.7
Mansonia	6,665	90.9	662	9.1	7,327	2.7
Psorophora	4	44.4	5	55.6	9	.0
Theobaldia	85	4.0	2,022	96.0	2,107	.8
Uranotaenia	19	.8	2,318	99.2	2,337	.8
Wyeomyia	9	36.0	16	64.0	25	0.0
Orthopodomyia	0	0.0	3	100.0	3	0.0
Total	23,484	8.6	249,603	91.4	273,087	100.0

The relative numerical importance of these genera is determined by two methods. Table XVII lists the genera and the relative numerical per cent of the total mosquito fauna in Massachusetts. This per cent distribution is calculated on the basis of the specimens collected. In this evaluation the genus *Culex* represents 78.7 per cent of the mosquitoes, the genus *Anopheles* 10.5 per cent, and the genus *Aedes* only 6.5 per cent.

The genera are broken down further into the number of larvae and adults collected, and the proportion of each to the total of the genus is expressed as a per cent. Among the specimens of *Anopheles* and *Culex*, larvae represented

the vast majority. Among *Aedes*, however, adult specimens comprised almost a half of the total. The other genera were collected in much smaller numbers. *Mansonia* larvae, because of their peculiar adaptation in attaching themselves to plants, were collected very infrequently.

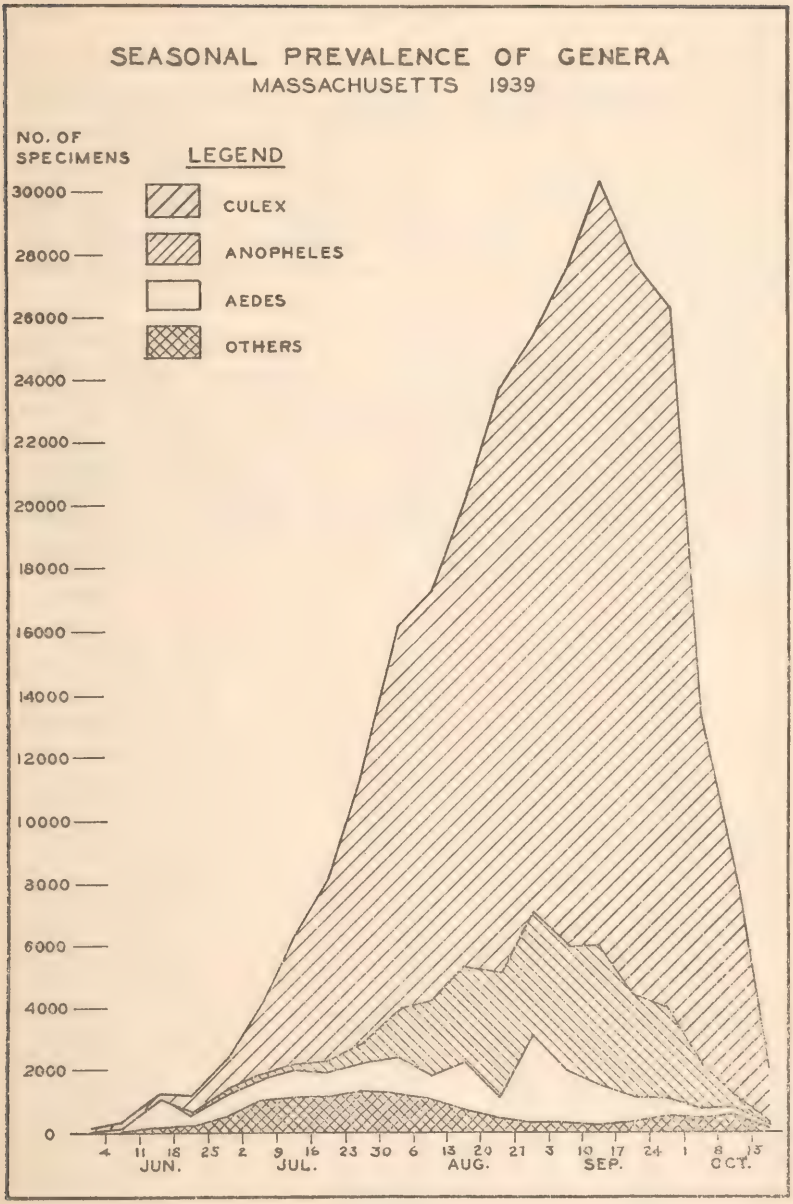
The number of specimens per collection of adults and larvae is summarized in Table XVIII. The larvae averaged 6.35 specimens per collection, which is more than twice the 2.94 average for adults. This difference in size of collections is due to two factors. The capture of a single adult often constituted a collection, while the larvae, usually found in larger aggregates, afforded the gathering of a larger number of specimens in a single collection.

TABLE XVIII. — *Average Number of Specimens per Collection.*

GENUS.	Larvae.	Adults.
Aedes	6.39	2.39
Anopheles	3.61	2.88
Culex	7.12	2.70
Mansonia	9.59	5.04
Psorophora	1.0	1.0
Theobaldia	7.17	1.35
Uranotaenia	3.34	1.5
Wyeomyia	8.0	9.0
Orthopodomyia	3.0	0.0
All genera	6.35	2.94

Seasonal Distribution.

Aedes mosquito collections were the most numerous when the survey began in July. Thereafter they continued to decrease as the season progressed. *Aedes* comprised over 50 per cent of all collections early in July, and less than 2 per cent late in August. *Anopheles* were most prevalent between the thirty-first and the forty-second week, that is, during August, September and early October, when this genus comprised 20 to 25 per cent of the collections. *Culex* continued to increase with the progress of the season, beginning with an initial 43 per cent in July and ending with 84 per cent in August. The seasonal curves are plotted in Graph III.


SEASONAL PREVALENCE OF GENERA
MASSACHUSETTS 1939
NO. OF SPECIMENS
LEGEND
CULEX
ANOPHELES
AEDES
OTHERS
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
4 11 18 25 2 9 16 23 30 6 13 20 27 3 10 17 24 1 8 15
JUN.
JUL.
AUG.
SEP.
OCT.

Graph III.

Species.

There are 56 species of mosquitoes in Massachusetts; 41 of these belong to the *Culicinae*, or biting mosquitoes. During the survey, 4 *Culicinae* and 2 *Chaoborinae* were collected in Massachusetts for the first time. Three species previously collected in the State were not included in the survey's findings. The total collections, as well as the number of specimens of adults and larvae, are summarized in Table XIX.

Table XIX is the presentation of data on the geographical distribution of the *Culicinae*. The figures indicate the number of collections made during the duration of the survey. Under each species the adults and larvae are considered separately. Dukes and Nantucket Counties are combined; these two counties are islands off the south coast of Cape Cod, are small in size and have similar characteristics.

TABLE XIX. — *Summary of Mosquitoes of Massachusetts.*

	Larvae.		Adults.	
	Number of Specimens.	Number of Collections.	Number of Specimens.	Number of Collections.
Subfamily Culicinae.				
Aedes atropalpus	993	77	50	41
A. aurifer	0	0	542	186
A. canadensis	495	122	770	301
A. cantator	2,704	399	1,326	600
A. cinereus	482	117	471	256
A. communis[1]	0	0	0	0
A. dorsalis	79	14	4	4
A. excrucians	41	15	485	269
A. fitchii	21	5	196	95
A. hirsuteron	4	4	7	4
A. implacabilis	10	3	29	16
A. impiger[1]	0	0	0	0
A. intrudens	48	8	295	131
A. punctor	0	0	6	5
A. sollicitans	1,054	146	2,548	856
A. stimulans	8	2	59	38
A. taeniorhynchus	112	17	20	8
A. trichurus	2	2	20	8
A. triseriatus	92	33	228	158
A. trivittatus	1	1	6	3
A. vexans	3,358	519	1,052	454
Total Aedes	9,504	1,484	8,124	3,433
Anopheles crucians[2]	20	7	0	0
A. maculipennis	113	58	30	5
A. punctipennis	20,396	5,757	300	192
A. quadrimaculatus	6,810	1,729	790	182
A. walkeri	84	31	57	28
Total Anopheles	27,423	7,582	1,177	407
Culex apicalis	78,944	13,051	1,746	688
C. pipiens	103,138	11,640	3,880	1,313
C. salinarius	2,215	922	832	339
C. territans	23,353	3,524	943	398
Total Culex	207,650	29,137	7,401	2,738
Mansonia perturbans	662	89	6,665	1,320
Orthopodomyia signifera[2]	3	0	0	0
Psorophora ciliata	2	2	4	4

[1] Not collected by survey.
[2] Recorded by survey for the first time in Massachusetts.

TABLE XIX. — *Summary of Mosquitoes of Massachusetts* — Concluded.

	Larvae.		Adults.	
	Number of Specimens.	Number of Collections.	Number of Specimens.	Number of Collections.
Subfamily Culicinae. — Con.				
P. columbiae[1]	3	3	0	0
P. posticata[2]	0	0	0	0
Total Psorophora	5	5	4	4
Theobaldia impatiens[1]	0	0	2	2
T. inornata	0	0	6	3
T. melanura	1,971	265	70	52
T. morsitans	51	17	7	6
Total Theobaldia	2,022	282	85	63
Uranotaenia sapphirina	2,318	693	19	12
Wyeomyia smithii	16	2	9	1
Total culicinae	249,603	39,254	23,484	7,978
Subfamily Chaoborinae.[3]				
Chaoborus	37	20	41	16
C. albatus	–	–	–	–
C. albipes	5	2	0	0
C. americanus	–	–	–	–
C. punctipennis	–	–	–	–
C. trivittatus	–	–	–	–
Total Chaoborus	42	22	41	16
Corethrella brakeleyi[2]	14	5	0	0
Dixa	195	84	11	6
D. centralis	–	–	–	–
D. clavata	–	–	–	–
D. cornuta	–	–	–	–
D. modesta	–	–	–	–
D. notata	–	–	–	–
Total Dixa	195	84	11	6
Eucorethra underwoodi[1]	3	3	0	0
Mochlonyx	24	11	0	0
M. cinctipes	–	–	–	–
M. fuliginosus	–	–	–	–
M. karnerensis	–	–	–	–
Total Mochlonyx	24	11	0	0
Total Chaoborinae	278	125	52	22
Grand total	249,881	39,379	23,536	8,000

[1] Recorded by survey for the first time in Massachusetts.
[2] Not collected by survey.
[3] Species not routinely identified by survey.

TABLE XX. — *Mosquitoes of Massachusetts, by Counties — Collections.*

[A. = Adults; L. = Larvae.]

County.	Aedes.																	
	atropalpus.		aurifer.		canadensis.		cantator.		cinereus.		dorsalis.		excrucians.		fitchii.		hirsuteron.	
	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.
Barnstable	6	–	64	–	92	21	163	184	41	50	2	10	87	3	58	5	2	1
Berkshire	–	–	3	–	4	3	–	–	9	3	–	–	1	–	2	–	–	–
Bristol	–	–	5	–	5	7	14	39	13	–	–	–	1	1	–	–	–	–
Dukes[1]	–	–	1	–	8	3	168	112	10	17	–	1	4	–	2	–	–	2
Essex	2	3	10	–	23	2	129	11	39	1	–	1	42	–	12	–	–	–
Franklin	26	29	1	–	8	1	–	–	2	–	–	1	2	–	1	–	–	–
Hampden	4	35	5	–	15	2	1	–	6	–	–	–	7	1	1	–	–	–
Hampshire	1	10	4	–	2	–	–	–	3	–	–	–	4	1	1	–	–	–
Middlesex	1	–	12	–	14	2	4	12	20	4	–	–	24	1	3	–	1	–
Norfolk	–	–	10	–	26	73	14	6	15	20	1	–	23	5	4	–	1	1
Plymouth	–	–	63	–	57	6	100	28	28	8	1	1	37	2	9	–	–	–
Suffolk	–	–	1	–	1	1	7	7	3	1	–	–	1	–	–	–	–	–
Worcester	1	–	7	–	46	1	–	–	67	13	–	–	36	1	2	–	–	–
Total	41	77	186	0	301	122	600	399	256	117	4	14	269	15	95	5	4	4

[1] Includes Nantucket.

TABLE XX. — *Mosquitoes of Massachusetts, by Counties — Collections* — Continued.

[A. = Adults; L. = Larvae.]

COUNTY.	AEDES.																			
	IMPLACABILIS.		INTRUDENS.		PUNCTOR.		SOLLICITANS.		STIMULANS.		TAENIORHYNCHUS.		TRICHURUS.		TRISERIATUS.		TRIVITTATUS.		VEXANS.	
	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.
Barnstable	7	–	51	3	4	–	196	48	19	2	–	–	6	–	5	–	1	–	126	167
Berkshire	–	–	3	–	–	–	–	–	–	–	–	–	–	–	12	2	–	–	12	59
Bristol	–	–	–	–	–	–	7	2	–	–	–	–	–	–	2	2	–	–	35	21
Dukes[1]	–	–	1	–	–	–	290	70	1	–	7	17	–	–	3	–	–	–	31	30
Essex	1	1	11	–	–	–	260	3	5	–	–	–	–	–	14	–	–	–	31	11
Franklin	–	–	2	2	–	–	–	–	1	–	–	–	–	–	33	2	–	1	21	24
Hampden	–	–	3	–	–	–	–	–	1	–	–	–	–	1	13	7	–	–	23	40
Hampshire	–	–	3	–	–	–	–	–	1	–	–	–	–	–	9	1	–	–	6	39
Middlesex	–	–	7	–	–	–	16	4	1	–	–	–	–	–	8	1	–	–	27	17
Norfolk	1	–	8	1	–	–	30	4	–	–	–	–	–	–	13	9	–	–	26	7
Plymouth	1	–	22	–	1	–	46	14	4	–	1	–	1	1	4	3	1	–	60	60
Suffolk	–	1	2	–	–	–	10	1	1	–	–	–	–	–	6	–	–	–	8	2
Worcester	6	1	18	2	–	–	1	–	4	–	–	–	1	–	36	6	1	–	48	42
Total	16	3	131	8	5	–	856	146	38	2	8	17	8	2	158	33	3	1	454	519

[1] Includes Nantucket.

TABLE XX. — *Mosquitoes of Massachusetts, by Counties — Collections* — Continued.

[A. = Adults; L. = Larvae.]

County.	Anopheles.										Culex.							
	crucians.		maculi-pennis.		punncti-pennis.		quadri-maculatus.		walkeri.		apicalis.		pipiens.		salina-rius.		territans.	
	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.
Barnstable	–	5	–	–	2	41	1	21	1	–	17	1,542	44	353	24	92	6	80
Berkshire	–	–	–	11	42	830	29	57	1	8	81	1,013	143	1,087	31	32	76	1,168
Bristol	–	–	1	2	12	244	11	152	1	2	12	577	33	568	19	75	6	98
Dukes[1]	–	–	–	–	–	5	–	–	–	–	7	393	26	470	12	251	10	101
Essex	–	1	2	1	15	292	60	619	12	6	24	654	63	1,435	22	137	29	409
Franklin	–	–	–	4	16	544	2	28	–	1	68	601	139	794	36	38	31	295
Hampden	–	–	–	5	21	1,343	4	189	–	4	8	821	33	325	2	7	9	130
Hampshire	–	–	–	2	3	146	5	9	–	1	6	540	13	464	3	5	7	236
Middlesex	–	–	–	4	22	447	14	178	–	3	347	1,536	391	3,188	96	105	103	476
Norfolk	–	–	–	2	2	129	20	117	2	2	4	404	69	1,230	12	79	25	271
Plymouth	–	1	–	6	5	392	14	241	4	–	38	2,203	50	515	12	57	0	54
Suffolk	–	–	–	–	2	3	1	2	–	–	5	8	61	340	12	7	15	8
Worcester	–	–	2	21	50	1,341	18	116	7	4	91	2,759	248	871	58	37	72	198
Total	0	7	5	58	192	5,757	182	1,729	28	31	688	13,051	1,313	11,640	339	922	398	3,524

[1] Includes Nantucket.

TABLE XX. — *Mosquitoes of Massachusetts, by Counties — Collections* — Concluded.

[A. = Adults; L. = Larvae.]

County.	Mansonia.		Psorophora.				Theobaldia.								Uranotaenia.		Wyeomyia.	
	perturbans.		ciliata.		columbiae.		impatiens.		inornata.		melanura.		morsitans.		sapphirinia.		smithii.	
	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.	A.	L.
Barnstable	337	61	–	–	–	–	–	–	–	–	5	99	–	4	1	49	–	2
Berkshire	34	–	–	–	–	–	–	–	–	–	–	–	1	–	1	39	1	–
Bristol	25	–	–	–	–	–	–	–	–	–	–	10	–	–	–	42	–	–
Dukes[1]	31	–	1	–	–	–	–	–	–	–	1	71	–	2	–	1	–	–
Essex	209	–	–	–	–	–	1	–	–	–	5	1	3	1	–	55	–	–
Franklin	11	–	1	–	–	–	–	–	–	–	4	1	–	–	–	3	–	–
Hampden	49	1	2	–	–	1	–	–	–	–	2	4	–	–	–	60	–	–
Hampshire	12	–	–	2	–	2	–	–	1	–	–	–	–	–	–	30	–	–
Middlesex	71	–	–	–	–	–	–	–	–	–	8	5	–	6	5	120	–	–
Norfolk	146	4	–	–	–	–	–	–	–	–	5	12	–	1	–	64	–	–
Plymouth	224	1	–	–	–	–	–	–	–	–	7	50	2	2	2	173	–	–
Suffolk	18	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–
Worcester	153	2	–	–	–	–	1	–	2	–	14	11	–	1	3	57	–	–
Total	1,320	69	4	2	–	3	2	–	3	–	52	265	6	17	12	693	1	2

[1] Includes Nantucket.

Public Health Importance of Aedes Species.

This survey was instituted because of the possible future recurrence of equine encephalomyelitis in the State. Since only *Aedes* mosquitoes apparently transmit the virus of the disease, a short résumé of the possible public health importance of each species of the genus is given below. Only 6 of the 23 have as yet been shown to transmit the virus, but others will undoubtedly be added to the list.

Aedes atropalpus. — This species has been demonstrated to transmit equine encephalomyelitis in the laboratory. Of the six vectors known to exist in Massachusetts, it is about fourth in numerical importance, comprising 7.77 per cent of the specimens of vectors. It was collected from three portions of the State, — the Connecticut Valley, Essex County and Cape Cod. In favorable years its distribution may be more widespread.

The mosquito breeds principally in clear water accumulated in rock formations, as in rivers, streams, ponds, lakes, marshes and swamps. It prefers sparsely populated areas. A few adults, not avid biters, were collected in houses and stables. The adults are prevalent during August and September. However, due to the peculiar geographical distribution, and to the small number of *A. atropalpus*, this species could not have played a large rôle in the 1938 outbreak of equine encephalomyelitis. It is probably not an important natural vector of the disease.

Aedes aurifer. — This species may be of no public health importance, as it has not yet been proven to be a vector of disease. However, it is one of the species which bites man freely. Its distribution was widespread throughout the State. All collections consisted of adults, and no larvae were found.

Matheson has had the same experience in Central New York, where adults are abundant and larvae have not been collected. The adults are apt to bite in the open and do not enter buildings as frequently as many of the other species. The adults are most prevalent early in the summer, and by August and September are comparatively rare.

Aedes canadensis. — This mosquito is not a proven vector of disease, but is important as a nuisance. The species is widely distributed throughout the State. Larvae were collected in small numbers, mainly in ponds and lakes, running and still water, and marshes and swamps in thinly settled regions. Although not ubiquitous, the larvae are found in many different types of breeding places. The adult bites man in the open, but does enter houses at times. The species is most numerous in the early summer; by July it is decreasing in number, and in August and September becomes rare.

Aedes cantator. — As a vector of equine encephalomyelitis, this species may be of great public health importance. Numerically, it is in first place among the vectors of equine encephalomyelitis in number of collections, and in second place in number of specimens. It is a salt marsh mosquito and limited, in geographical distribution, to the coast and adjacent regions. Usually the adults were within ten miles of the nearest salt water; rarely were they found fifteen miles from their breeding places. The larvae were collected in largest numbers from coastal marshes and swamps, and streams and rivers. Dumps, cranberry bogs and barrels were the most frequent man-made breeding places. The adults bite man principally in the open, but enter houses as well, although in much smaller numbers than certain other mosquitoes. They have been collected in houses, barns and stables, and in the vicinity of horses and birds which are known to be susceptible to equine encephalomyelitis. The species was most numerous in September and October, when these adults represented 15 per cent of the total adult collections.

This mosquito is one of the three most numerous vectors of the virus of equine encephalomyelitis. Its seasonal distribution coincides with that of the disease. Although the geographical distribution is not entirely the same, the mosquito was collected from some parts of the area where the outbreak occurred, namely, in Bristol and Plymouth Counties.

Aedes cinereus. — This *Aedes* mosquito is not a proven

vector of disease, but it is a fierce biter. It is distributed throughout the State, but largest collections were made in the eastern portion. The larvae were found most frequently in marshes and swamps and in running and still water, in less thickly settled areas. Although the adults bite man in the open, the mosquito has been collected in houses, barns and stables. Some adults were collected from a horse, and still others were caught in the vicinity of cattle, horses and mules. The adults were caught in largest numbers early in the season, and gradually decreased throughout the summer and autumn. Larvae were collected as late as September, although not to a great extent. This species may be a nuisance early in the spring, but is probably of no importance as a vector.

Aedes communis. — This species was reported by Johnson in 1925 as found in Massachusetts. However, it was not collected during the survey. Matheson states that the adults appear early in spring and persist until late in the season. He collected the larvae from spring pools, swamps and marshes. This species is probably very unimportant, as it was not picked up in the 49,000 collections made during the survey.

Aedes dorsalis. — This species is one of the rarer *Aedes* mosquitoes. It is not an important biter and is not known to transmit the eastern virus, though it does transmit the western virus of equine encephalomyelitis. Scattered collections were made in Franklin County in the west, and along the coastal region in the east. Insufficient collections of larvae were made to ascertain the typical breeding places of this species, and the adults were collected even less frequently. One collection of this species was made on man. The species is apparently most abundant early in spring, becomes rare in July, and remains so for the rest of the season.

Aedes excrucians. — This mosquito is of little importance as a biter. It was found to be state wide in distribution. The larvae were collected in small numbers; two collections were made in cranberry bogs and one in a dump. The adults bite man and were collected in houses, barns and

stables. The adults appeared early in spring and were rare by September. In spring this species may be a nuisance outdoors in certain districts.

Aedes fitchii. — Little concern is expressed over this mosquito, as it is not a fierce biter and probably plays no rôle in the spread of disease. This species was collected in scattered areas throughout the State. Adults, which were collected on man and in houses and barns, were found only during the early part of the season. Larvae were found in very small numbers. The species is definitely a spring and early summer mosquito.

Aedes hirsuteron. — This species is quite rare in Massachusetts. Small collections were made along the coastal regions. *Aedes hirsuteron* is of no public health importance, as it seldom bites man and occurs in small numbers. The seasonal prevalence of this species cannot be determined from the collections made during the survey.

Aedes impiger. — This species was not collected by the survey. Johnson reported it from Massachusetts in 1925. It is rare and little is known about its habits. It is, therefore, an unimportant mosquito.

Aedes implacabilis. — This is another rare species of *Aedes.* The adults were collected during July and August, and the larvae were found in small numbers throughout the season. It is an early mosquito, with a spring and early summer predominance. The mosquito is unimportant, as it is a rare species, is not a fierce biter, and is not known to transmit disease.

Aedes intrudens. — Since this species bites man in the open it may be important as a nuisance. It was distributed throughout the State. Larvae were collected in small numbers from cranberry bogs, cesspool overflows and dumps. The adults were captured in houses and on man. The mosquito was most numerous in the early summer and became rare in August and September.

Aedes punctor. — This is a rare species of which only adults were collected. These collections were made in Plymouth and Barnstable Counties. One collection of adults was made in a house. It is an unimportant mosquito.

Aedes sollicitans. — This salt marsh mosquito, a fierce biter, is one of the most numerous of the vectors of the virus of equine encephalomyelitis. Geographically, it is limited to the vicinity of salt or brackish water. The adults were rarely collected more than fifteen miles from the nearest salt water. Larvae were collected in largest numbers from marshes and swamps. Of all species, *Aedes sollicitans* was captured most frequently on man. It was collected in houses with the same frequency as *Aedes cantator*, but less frequently in barns and stables. Collections of adults were made in the vicinity of horses, mules, cattle and birds which are susceptible to equine encephalomyelitis.

This species was most numerous in August and September. This seasonal prevalence coincides with that of the disease. As in the case of *Aedes cantator*, the geographical limitation of this mosquito was not the same as that of the disease in 1938. However, mosquitoes were much more prevalent during the outbreak, and this species may have been present in 1938 in areas in which it was not found in 1939.

Aedes stimulans. — This mosquito is not known to transmit disease; it is not a fierce biter and is numerically unimportant. Larvae were collected in scattered areas throughout the State. Adults were captured on man in two instances; a collection was made in a stable and in a house. This species predominates in the spring and by August is quite rare.

Aedes taeniorhynchus. — This southern salt marsh mosquito is a vector of equine encephalomyelitis. It is a fierce biter, but occurs in such small numbers and is so limited in geographical distribution that it is not of any great public health importance. Its collection was limited to the island of Martha's Vineyard and to the Buzzard's Bay region of southern Massachusetts. Larvae were found in marshes and swamps. Since most of the adults were captured on man outdoors, this species probably does not frequent houses. The adults were captured in August and September, and it is apparent that the species is most numerous at this time.

It is very unlikely that *Aedes taeniorhynchus* played a rôle in the 1938 outbreak of equine encephalomyelitis, unless its distribution extended farther northward in 1938 than it did in 1939.

Aedes trichurus. — This is a rare species which is unimportant as a nuisance and as a public health menace. This mosquito was collected so infrequently that no conclusions concerning its life habits can be made. It is probably an early mosquito with a spring predominance.

Aedes triseriatus. — Laboratory experiments have demonstrated that this species can transmit equine encephalomyelitis. It was found to be state wide in distribution, but was less numerous than *Aedes vexans* which is another vector of this disease. The larvae were collected from barrels, wells, dumps and water troughs. Adults were captured in houses more frequently than on man. Collections were made as frequently in thickly settled areas as in rural sections. The species was most numerous in August and the first three weeks of September, but decreased rapidly during the last week of September.

Aedes trivittatus. — This is a rare species of very little importance; *Aedes trivittatus* larvae were collected in two towns and adults in three. Since collections were so few it is impossible to draw any conclusions as to the life habits or seasonal predominance. Nine adult specimens were collected in houses; one collection was made in the vicinity of cattle and two in the vicinity of horses.

Aedes vexans. — This species, a demonstrated vector of equine encephalomyelitis, is state wide in distribution and one of the most numerous of the vectors. The larvae are ubiquitous in their breeding habits; collections were made from marshes, swamps, ponds, lakes, streams, rivers, cranberry bogs, puddles, dumps, barrels, a water trough, a well and a rocky crevice. The adults are fierce biters and were frequently collected on man, in stables, barns and in houses. Although more collections were made in rural areas, urban communities were not without this mosquito. This species was collected more frequently in barns and stables than any other *Aedes*. It was also captured in the

vicinity of horses, mules, cattle and many kinds of birds. *Aedes vexans* was the most prevalent in August and September. It was present in large numbers in July, and probably would have been present in larger numbers were it not for the drought in June and July.

It is conceivable that this species was involved in the 1938 outbreak of equine encephalomyelitis. It is the only numerous vector that was found in all areas where the disease occurred. In fact, its distribution was far more extensive than the area involved in the outbreak. It was the most numerous of the vectors if the number of specimens is considered, and second most numerous on the basis of collections. It is not unlikely that *Aedes vexans* may prove to be the most important natural vector of equine encephalomyelitis.

Summary and Conclusions.

1. The information regarding mosquito breeding collected in this survey should be valid for many years. Breeding habits of these insects are well stabilized, and changes develop very slowly. There is likewise little prospect that large works which will affect mosquito breeding, such as the development of the Quabbin Reservoir in the Swift River Valley, will be undertaken in the near future.

2. While this survey was made in a dry year, it is believed that differences which result in wet years will be largely quantitative rather than qualitative. The available places for breeding will be both larger and more numerous, and water collections will persist for periods long enough for larvae to develop into the adult stage.

3. The difficulty experienced in collecting larvae in the salt marsh areas, where control work under the supervision of the Reclamation Board is being done, gives assurance that this control work is proving effective where the ditches are well laid out and maintained.

4. There is reason to believe that horse sleeping sickness might have been more prevalent in the salt marsh areas in 1938 if these salt marsh mosquitoes, most of which have been shown to be able to transmit the virus, had been as

numerous as they were previous to 1930 when the control work was begun.

5. The problem of the control of fresh-water mosquitoes is much more difficult than the control of salt-marsh mosquitoes. The breeding places are not only more numerous, but there is a great diversity in the types of water collections. Control measures are both more difficult to plan and carry out and more costly to execute. Because of the expense, it will not be feasible to undertake extensive control except when some disease, such as horse sleeping sickness, is being spread by fresh-water mosquitoes. In such cases the control measures should be aimed at the species known to be responsible for the spread. This survey was undertaken to collect information to form the basis for directing such efforts when and if the need arises.

6. Because no large scale control measures of fresh-water mosquitoes have ever been undertaken in this State, and because it seems likely that *Aedes vexans*, a fresh-water mosquito, was responsible for the spread of horse sleeping sickness (equine encephalomyelitis) in 1938, control work on an experimental basis should be undertaken in selected areas to discover what methods will prove most effective for the types of breeding places in this region. Such work might well be undertaken, under the supervision of the Reclamation Board, in areas where mosquitoes have been pests, such as the Charles River Valley, or in areas where the control works may be partly justified by land reclamation or other reasons, such as the draining of the Hockamock or Great Cedar Swamp in Easton, Taunton and surrounding towns.

Respectfully submitted,

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